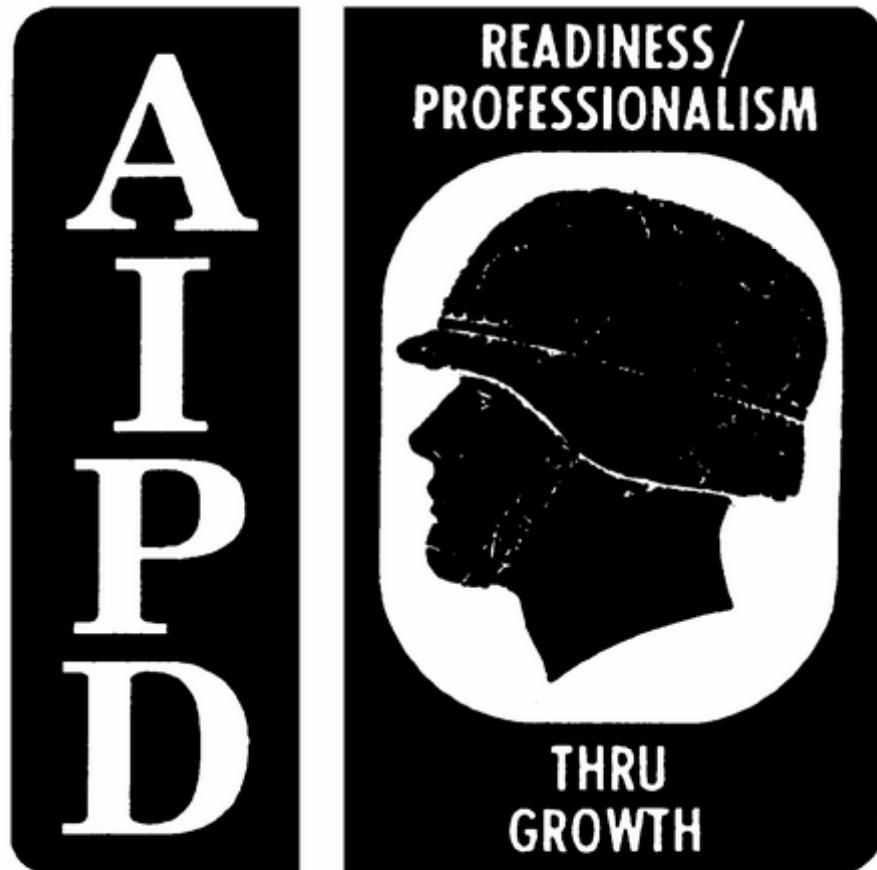


SUBCOURSE
EN0069

EDITION
A

FRAME STRUCTURES



THE ARMY INSTITUTE FOR PROFESSIONAL DEVELOPMENT
ARMY CORRESPONDENCE COURSE PROGRAM

**ENGINEER
SUBCOURSE 69**



**FRAME
STRUCTURES**

**CORRESPONDENCE COURSE
U.S. ARMY ENGINEER SCHOOL**

***** IMPORTANT NOTICE *****

THE PASSING SCORE FOR ALL ACCP MATERIAL IS NOW 70%.

PLEASE DISREGARD ALL REFERENCES TO THE 75% REQUIREMENT.

INTRODUCTION

The erection of frame structures has been an important responsibility of Army engineers since Washington's day. Large-scale operations of recent times conducted in relatively undeveloped areas such as the Pacific region in World War II, Korea, and Vietnam resulted in the expenditure of tremendous effort on frame structures. This experience, plus the threat of nuclear conflict and the need for frame buildings in nonwar situations, makes it highly likely that you, as an engineer, will, from time to time, be responsible for some phase of this kind of construction.

The objective of this subcourse is to provide you with the fundamentals of planning and supervising the construction of frame structures which comprise the basic type of building in a theater of operations. It will also orient you in the fundamentals of construction print reading. You will learn about building layout procedures; framing details of substructures, superstructures, and roofs; kinds and properties of timber; and planning and estimating material and labor requirements for frame construction. Emphasis is on simplified theater-of-operations construction. However, some details of conventional construction are also included for use as a general guide and for use in rehabilitation and repair of existing structures.

The subcourse consists of five lessons and an examination divided as follows:

Lesson

- 1. Construction Print Reading - Building Layout and Substructures.
- 2. Superstructures - Framing.
- 3. Roofing-Finishing Details.
- 4. Materials Estimating.
- 5. Construction Methods and Standards - Planning Estimates.

Examination.

Fourteen credit hours are allowed for the Subcourse.

You will not be limited as to the number of hours you may spend on the subcourse, the solution to any lesson or the examination.

The format of this subcourse has been changed to facilitate student self-pacing and to eliminate the necessity of submitting to the USAES each lesson answer sheet for grading. Each lesson in this subcourse is followed by a number of Self Test questions and exercises designed for a review of that lesson. After completing study of the lesson, you should answer the questions in the space provided below each, then turn to the back of the subcourse booklet where the correct answers to the Self Test have been included. A comparison of your answers with those given in the back of the subcourse will indicate your knowledge and understanding of the material presented. When you have completed all lessons to your satisfaction, complete and forward the Examination answer card which you will find in the subcourse packet. The grade you receive on the examination is your grade for the subcourse.

LESSON 1

CONSTRUCTION PRINT READING - BUILDING LAYOUT AND SUBSTRUCTURES

CREDIT HOURS.....	3
TEXT ASSIGNMENT.....	Attached memorandum.
MATERIALS REQUIRED.....	None.
SUGGESTIONS.....	Pay particular attention to nomenclature. A construction supervisor must be thoroughly familiar with the names of building members.

LESSON OBJECTIVES

Upon completion of this lesson you should be able to accomplish the following in the indicated topic areas:

1. Prints and drawings. Read and interpret correctly, construction prints and architectural drawings.

2. Lumber. Define the different types of wood, good and bad features of each type, defect,

causes of deterioration, standard sizes, grades, and the meaning and method of calculating board feet.

3. Methods of fastening. Describe the different methods commonly used for fastening wood and the circumstances under which each type would be used.

4. Building layout. Supervise the layout of a frame building from the installation of batter boards through laying of the subfloor.

ATTACHED MEMORANDUM

1-1. TYPES OF BUILDINGS

Army regulations classify all buildings constructed or used by the Army as permanent, semipermanent, or temporary. The basis for classification is as follows:

a. Permanent buildings are those which are laid out and designed to have a degree of structural adequacy, durability, and service-ability to assure a useful life of 25 years or more with low maintenance and service expenditures.

b. Semipermanent buildings are those which by the design, use of materials and equipment, and methods of construction will, with normal maintenance, provide structures with an economic life of less than 25 years and more than 5 years.

c. Temporary buildings are those which by design and the use of minimum-quality materials, equipment, and methods of construction will, with minimum maintenance, provide structures with an economic life of 5 years or less. This group of buildings includes:

(1) Factory-fabricated type buildings which can be readily erected and dismantled.

(2) Emergency construction type buildings.

(3) Buildings constructed for temporary use, to include expedients. The subject matter of this subcourse applies particularly to the frame structures used in a theater of operations (TO). As an engineer officer, you may be expected to take charge of this type of building operation.

1-2. ARCHITECTURAL DRAWINGS AND PRINTS

a. Basic to the successful accomplishment of any building construction assignment is the ability to read architectural drawings or prints. It can be extremely difficult for an individual to describe the size and shape of a simple object without a drawing of some kind. For example, if an architect designed a simple structure, it would be difficult to convey his idea to the person who is to fabricate the structure without a drawing to show the shape, size, and spacing of members.

b. Drawing or sketching is the universal language used by engineers, technicians, and skilled craftsmen. Whether this drawing is made freehand or by the use of drawing instruments (mechanical drawing), it is needed to convey all the necessary information to the individual who will fabricate and assemble the object whether it be a building, ship, aircraft, or a mechanical device. If many people are involved in the fabrication of the object, copies will be made of the original drawing or tracing so that all persons involved will have the same information.

c. Drawings are normally classified as original drawings, intermediate or reproducibles, or prints. The original drawing is the one produced by the draftsman. An intermediate is a copy of the original which is used to make prints. An intermediate is used to avoid the risk of damaging the original or because the original is not suitable for the type of reproduction process used for the making of prints. Prints may also be made directly from the original without using an intermediate drawing. A print is a working copy to be used on the job.

d. There are many processes used to make intermediates and prints. They can be classified as either negative or positive contact processes or optical processes. Contact processes require a transparent or translucent original. Optical copies can be made from opaque originals. They are usually more expensive and introduce more distortion.

(1) Negative contact processes.

(a) Blueprints. A blueprint is made by placing a tracing (transparent or translucent original) in contact with a sensitized paper and exposing the paper through the tracing. When the paper is developed, the unexposed portions where the light is blocked by lines on the original remain white, while the exposed portions turn dark blue. This produces a print with white lines on a blue background. Blueprints, in general, have better contrast than other commonly used processes of comparable cost but the wet developing process causes some distortion, and marking the prints is difficult.

(b) Brownprints. The brownline print process (often called Van Dyke) is similar to the blueprint process except that the paper is transparent and exposed areas turn brown when developed. This yields transparent lines on a brown background. Brownprints are frequently used as intermediates producing a print which has blue lines on a white background and called whiteprint.

(2) Positive contact processes.

(a) Ozalid prints. The ozalid process is a contact process like blueprinting but the unexposed areas of the sensitized paper turn blue when developed in ammonia vapor, producing blue lines on a white background. These are called blueprints. Papers are also available which yield black lines (called blackline prints). The development in this process is dry, causing less distortion than the blueprint process, but the contrast is usually not as good. These are normally used for Army prints.

Note: Machines are available which produce ozalid-process prints but which project and reduce the

image optically instead of contact-printing. Prints produced by this process will usually be marked "Reduced Size Print-Do Not Scale."

(b) Brownline prints. Brownline paper has the same function in the ozalid process as the brown papers do in the blueprint process. They produce brown lines on a transparent background and are often used as an intermediate for making blueline prints. Brownline prints are often called sepia intermediates.

(c) Special materials. Materials are available for use with the ozalid process which produce a large variety of results, including many colored lines on white paper or colored lines on a clear plastic background.

1-3. LINE CONVENTIONS

Lines are symbols used on prints to show information necessary for construction. Figure 1-1 shows the types of lines commonly used on drawings and prints.

a. Visible lines. A heavy- or medium-weight unbroken line is used for the primary feature of a drawing. For drawings of objects, this line convention represents the edges, the intersection of two surfaces, and the surface limit that is visible from the viewing angle of the drawing. This line is often called the outline.

b. Hidden lines. A medium-weight line of evenly spaced short dashes represents an edge, the intersection of two surfaces, and the surface limit which is not visible from the viewing angle of the drawing.

c. Center lines. A thin (light) line composed of alternate long and short dashes is called a center line. It is used to signify the center of a circle or arc and to divide objects into equal or symmetrical parts.

d. Cutting plane lines. A pair of short, heavy lines with arrowheads projected at 90° indicates the cutting plane when a drawing includes a section. Letters (A-A, B-B, etc.) are usually placed at the arrowheads to identify the section. The arrowheads show the viewing direction of the

section. Where necessary, the section lines may be connected by a line of short, heavy dashes indicating the exact path of the cutting plane.

e. Dimension lines. Dimension lines are thin (light) unbroken lines with arrowheads used to indicate the extent of a dimension on a drawing. The dimensions may be placed above the dimension line, on a break in the dimension, or, where space is limited, as close as possible to the end of the dimension line. The extent of the dimension is from arrow head to arrowhead, and is expressed in feet and inches on civil engineering drawings.

f. Extension lines. When it is not convenient to draw a dimension line directly between the visible lines it applies to, the visible line is extended by a thin (light) unbroken extension line which almost touches the end of the visible line. The extension line indicates the extent of the dimension lines which have an arrow touching it.

g. Break lines. The break line indicates that the object has been shortened to save space on the drawing. The true length is indicated by the dimension specified. The long break line is a thin (light) line interrupted by a z-shaped symbol. The short break line convention varies with shape and material, and indicates that part of the object has been cut away to show section detail or hidden features.

1-4. SCALES AND SCALING

Measuring dimensions on a print is called scaling. Due to possible distortion of the print, scaling should be avoided as much as possible. When scaling is essential, however, be sure to check for accuracy by applying the scale you are using to one or more of the important dimensions normally shown on a print.

a. Types of scales

(1) Architects'. Architects' scales (1, fig. 1-2) are divided **proportionally** into feet and inches and are generally used in scaling drawings for machine and structural work. The triangular architects' scale usually contains 11 scales, each subdivided differently. Six scales read from the left end, while five scales read from the right end. 1, figure 1-2 shows how the 3/16-inch subdivision at the end

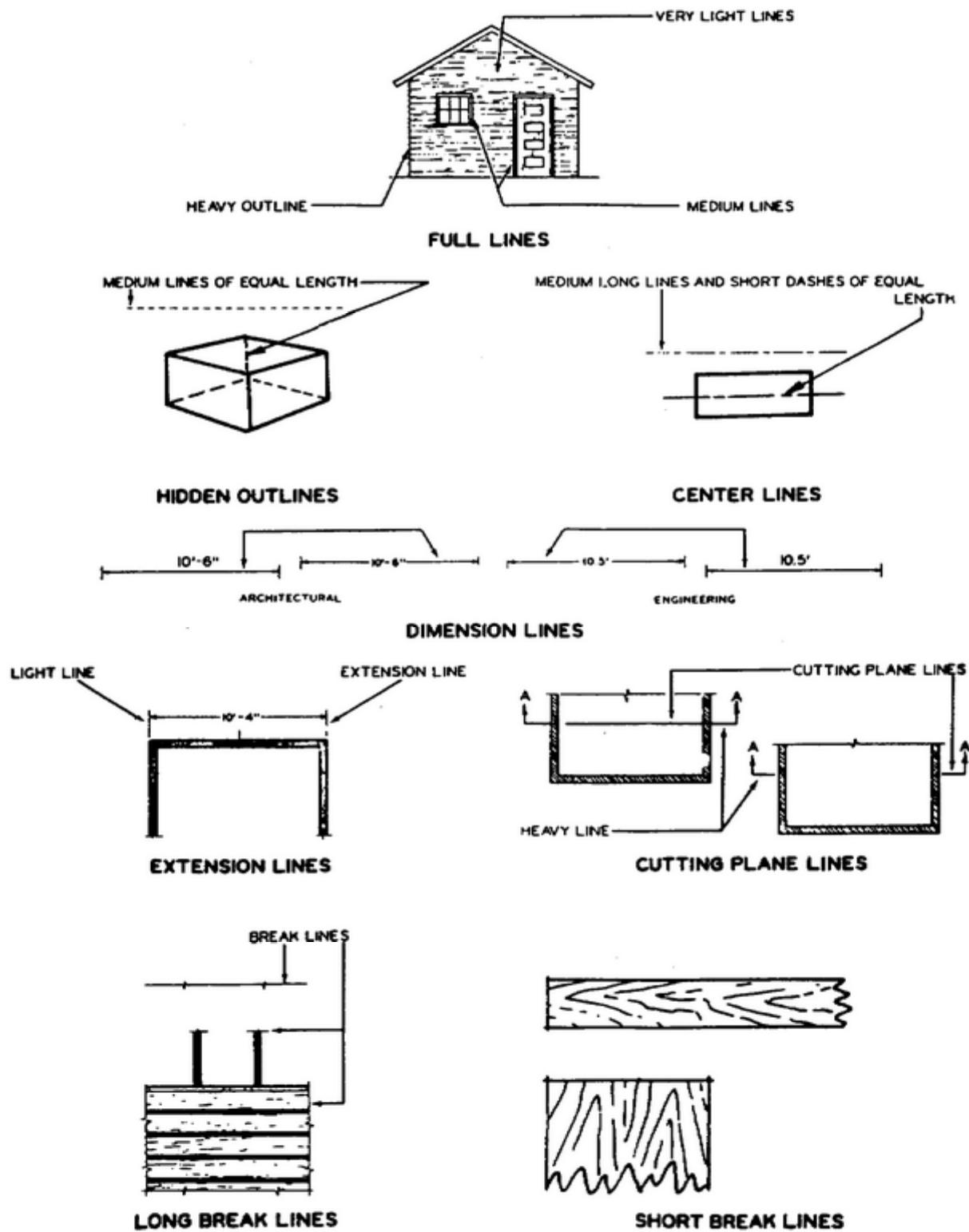
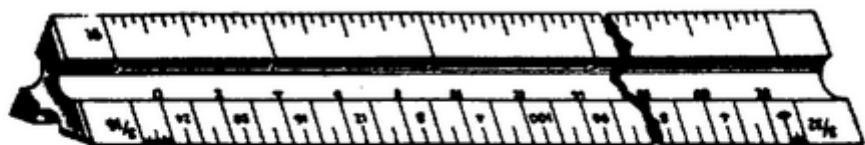
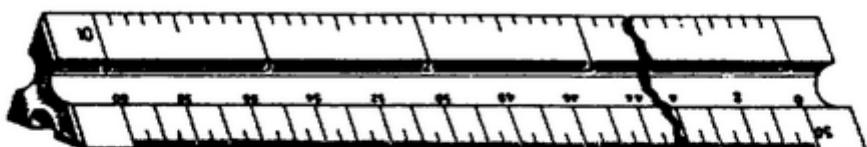


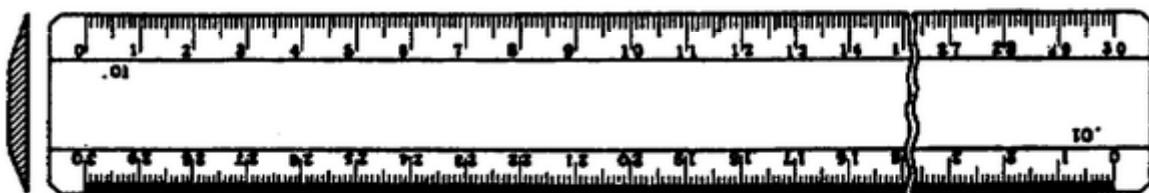
Figure 1-1. Types of lines and convention breaks.



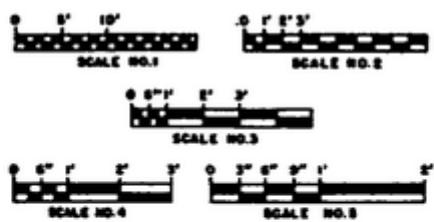
①

ARCHITECTS' SCALE

②

ENGINEERS' SCALE

③

METRIC SCALE

④

GRAPHIC SCALES*Figure 1-2. Types of scales.*

of the scale is further subdivided into 12 equal parts representing 1 inch each and the 3/32-inch subdivision into six equal parts representing 2 inches each.

(2) Engineers'. Engineers' scales (2, fig. 1-2) are divided into decimal graduations (10, 20, 30, 40, 50, and 60 divisions to the inch). These scales are used for plotting and map drawing and in the graphic solution of problems.

(3) Metric. Metric scales (3, fig. 1-2) are used in conjunction with the drawings, maps, and so forth that are made in countries using the metric system. This system is also being used with increasing frequency in the United States. The scale is divided into centimeters and millimeters. In conversion, 2.54 centimeters (cm) are equal to 1 inch.

(4) Graphic. Graphic scales (4, fig. 1-2) are lines subdivided into distances corresponding to convenient units of length on the ground or of the object represented by the tracing. The graphic scale is placed in or near the title block of the drawing, and the relationship of its length to the scale of the drawing is not affected if the drawing is reproduced

as a reduced or enlarged print. This type of scale is used with standard Army plans for frame structures.

b. Methods of scaling.

(1) Architects' or engineers' scales.

The method of scaling using architects' or engineers' scales is as follows:

(a) Determine the SCALE of the print from the notation given such as 1/4 inch = 1 foot-0 inches; 1 inch = 20 feet; 3/16 inch = 1 foot-0 inches and so forth.

(b) Select the corresponding scale on the architects' or engineers' scale.

(c) Using the proper scale, measure the desired dimensions on the print. Figure 1-3 illustrates the use of an architects' scale. Note that alining the 1-foot mark with the right hand end of the footing gives a direct reading of 1 foot, 9 inches for the length of the footing.

(2) Graphic scales. The procedure normally used with graphic scales is as follows:

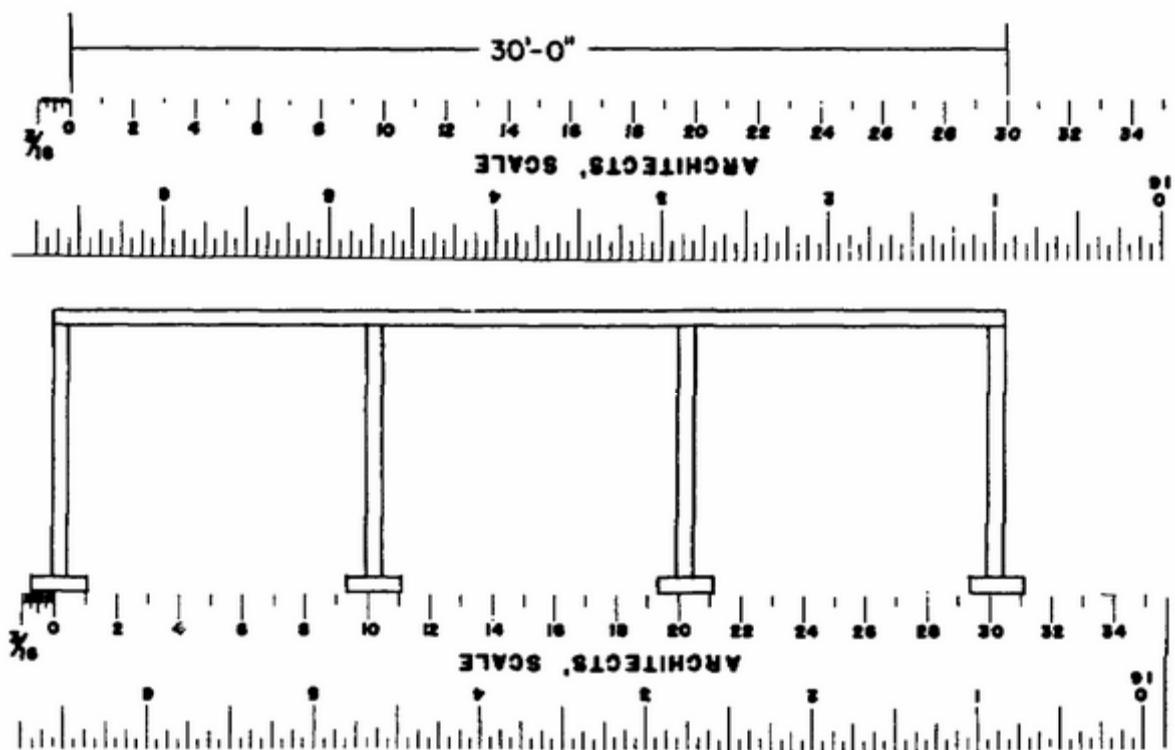


Figure 1-3. Scaling a dimension.

(a) On a slip of paper, mark off the length of the dimension desired.

(b) Place the slip on the graphic scale, reading off the dimension represented by the line length.

1-5. VIEWS

An architectural drawing consists of several views, each showing the building or structure in two dimensions. It usually includes elevations of the front, side, and rear; plans of floor and roof; and sectional views of construction details. In addition, detail and three-dimensional (perspective and isometric) drawings of special construction features are sometimes used to supplement two-dimensional views.

a. **Elevation.** Elevation drawings show the front, sides, and rear of buildings in true proportion. Figure 1-4 illustrates the development of elevations of front and side from a simple block to a small theater-of-operations type building. The sides may be specified as right or left with respect to the front view, or according to the point of the compass from which the view is taken, for example, north elevation. Elevations show floor level, grade lines, window and door heights, and the various materials to be used.

b. **Plans.** Drawings showing the interior arrangements of a building are called plans. These drawings are made looking down on the building from a point directly above. Horizontal surfaces, such as floors, appear without distortion. Figure 1-4 also shows the plan development of a typical TO building. All vertical surfaces, such as walls, appear as lines. Plans show the following information:

- (1) Outside shape of building.
- (2) Arrangement of rooms.
- (3) Size and shape of rooms.
- (4) Type of materials.
- (5) Thickness of walls and partitions.
- (6) Type, size, and location of doors and windows.
- (7) Details of framework and structure.
- (8) Type, size, and location of mechanical equipment such as heating plant, radiators, plumbing, and electrical wiring.

(9) Instructions concerning actual construction and installation work.

c. **Sections.** Sectional views show how a structure looks when cut vertically by a cutting plane. They give details which cannot be shown on elevation or plan views. Figure 1-4 illustrates the development of a sectional view of a typical theater-of-operations type building.

d. **Details.** A complete set of prints includes large-scale drawings of some parts of the building which cannot be shown clearly on the smaller scale drawings of overall plans and elevations. Details may be shown in elevation, plan, and section.

1-6. SYMBOLS AND SPECIFICATIONS

a. **Symbols.** Architectural drawings are simplified by the use of conventional symbols to represent certain parts of the building, various types of construction materials, and the utilities that are to be installed. Figure 1-5 shows the symbols recommended by the United States of America Standards Institute for the more common types of building materials. Figure 14 shows the symbols used to represent the doors and windows most commonly found in theater-of-operations type construction.

b. **Specifications.** Even with the most elementary of structures it is seldom possible to include in the actual drawings of floor plans, elevations, sections, and details, all the information required for construction. Notations on drawings or prints that explain materials or construction methods that cannot be indicated by symbols are called specifications. For example, "40-pound prepared roofing" indicates the material to be used to cover the roof; "notch post for handrail" indicates a construction detail. Those notations must always be read before beginning construction.

1-7. NOMENCLATURE

Figure 1-7 illustrates and identifies the principal elements of substructures as used in theater-of-operations (TO) frame structures.

1-8. JOINTS

Joints are connections between two pieces of lumber or timber that come together at an angle. Common types include:

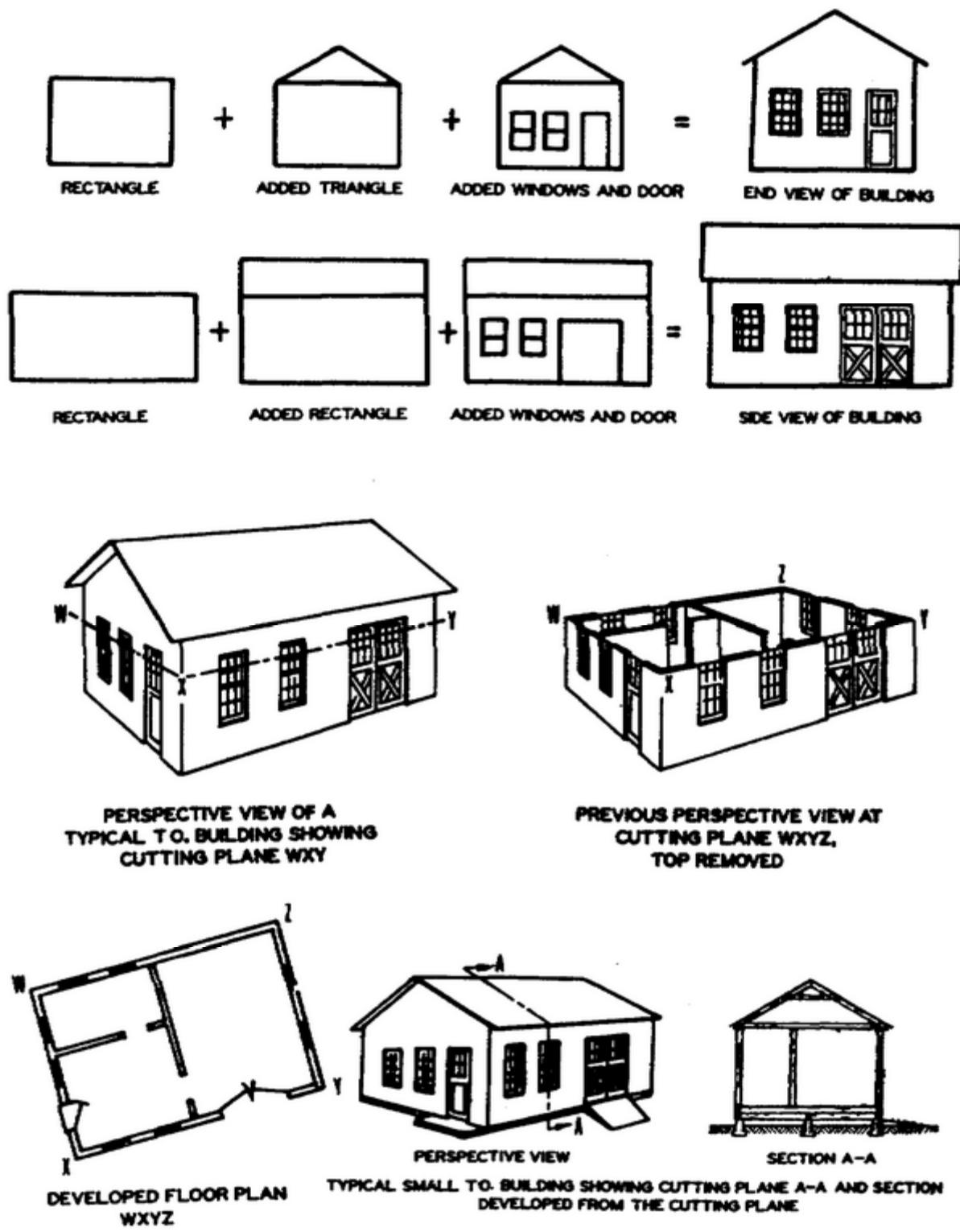


Figure 1-4. Architectural views.

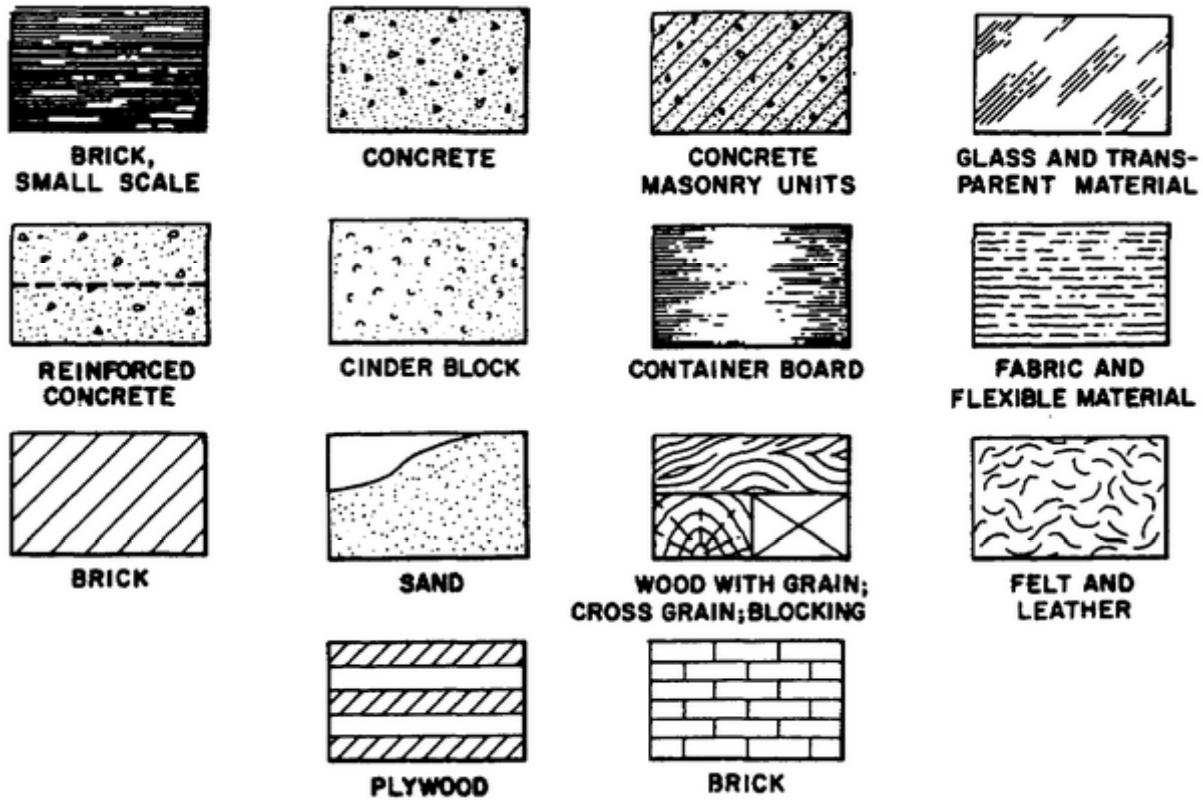


Figure 1-5. Material conventions.

TYPICAL DOOR SYMBOLS

SINGLE DOOR,
OPENING IN



DOUBLE DOOR,
OPENING IN



SINGLE DOOR,
OPENING OUT



DOUBLE DOOR,
OPENING OUT



SINGLE DOOR,
INTERIOR



DOUBLE DOOR,
INTERIOR



DOUBLE-ACTING
SINGLE DOOR



IN AND OUT
DOORS



REFRIGERATOR
DOOR

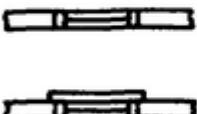


SLIDING DOORS

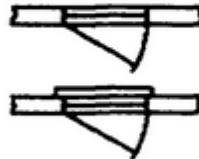


TYPICAL WINDOW SYMBOLS

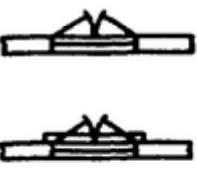
DOUBLE HUNG



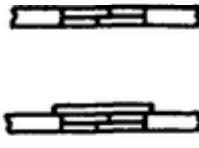
SINGLE,
OPENING IN



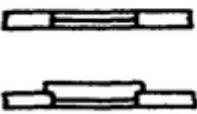
DOUBLE,
OPENING OUT



RIGHT SASH
OVER LEFT



PIVOTED AND
VENTED



LEFT SASH
OVER RIGHT



Figure 1-6. Typical door and window symbols.

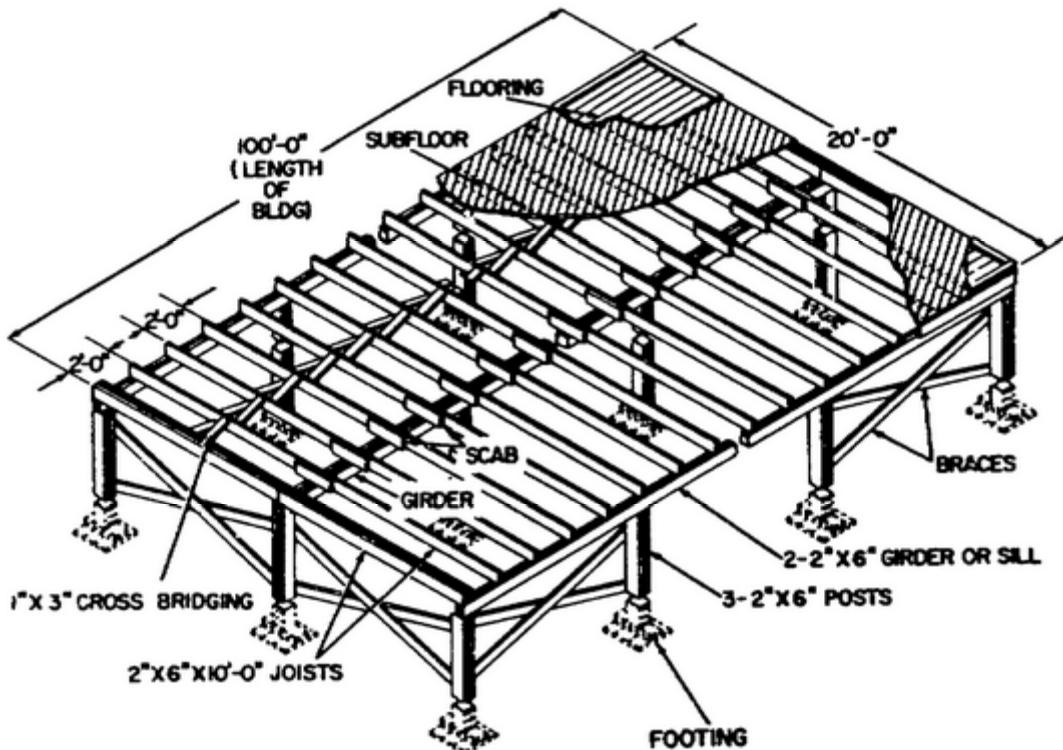


Figure 1-7. Substructure nomenclature.

a. Straight butt joint. Thin joint is formed by bringing the square-cut end of one piece against the face of another (1, 2 fig. 1-8). Screws will hold such a joint most securely, but for framing, butt joints are toenailed with or 10-penny nails. Nails should always be slanted because nails driven into wood parallel to the grain have very little holding power.

b. Oblique butt joint. This joint is formed by bringing the end of one piece, cut on the oblique to form the desired angle, against the face of another piece to which it is to be joined (3, fig. 1-8). Nails should be toenailed and the use of too many or too large nails avoided.

c. Miter butt joint. This joint is formed by bringing the mitered ends of two pieces together. The end of each piece cut to the same angle (4, fig. 1-8). The miter joint is extensively used in trim work around windows and doors, but its principal use in framing is for rafter junctions at roof peaks.

d. Plain lap joint. This joint is formed by laying one piece over another and fastening the two together with bolts, screws, or nails (5, fig. 1-8).

e. Half-lap joint. This joint is constructed by cutting away a portion (usually half) from the thickness of each of two pieces and joining them so that the cut-away portions overlap in a complementary manner to form a joint (6, fig. 1-8). Variations of the half lap include cross lap (7, fig. 1-8), middle lap (8, fig. 1-8), and mitered half lap (9, fig. 1-8).

f. Dado and rabbet joints. A dado is a square-bottomed, two-sided groove cut in wood, and a rabbet is a square-bottomed, one-sided groove or lip cut in the end of a piece. Principal joints include dado joint (1, 1-9), rabbet joint (2, fig. 1-9), dado-rabbet joint (3, fig. 1-9), and stopped dado (4, fig. 1-9).

g. Dovetail and mortise-and-tenon joints. These locked joints give added strength but require additional work and greater skill. The most common locked joints are lap dovetail (5, fig. 1-9), through single dovetail (6, fig. 1-9), open mortise-and-tenon (7, fig.

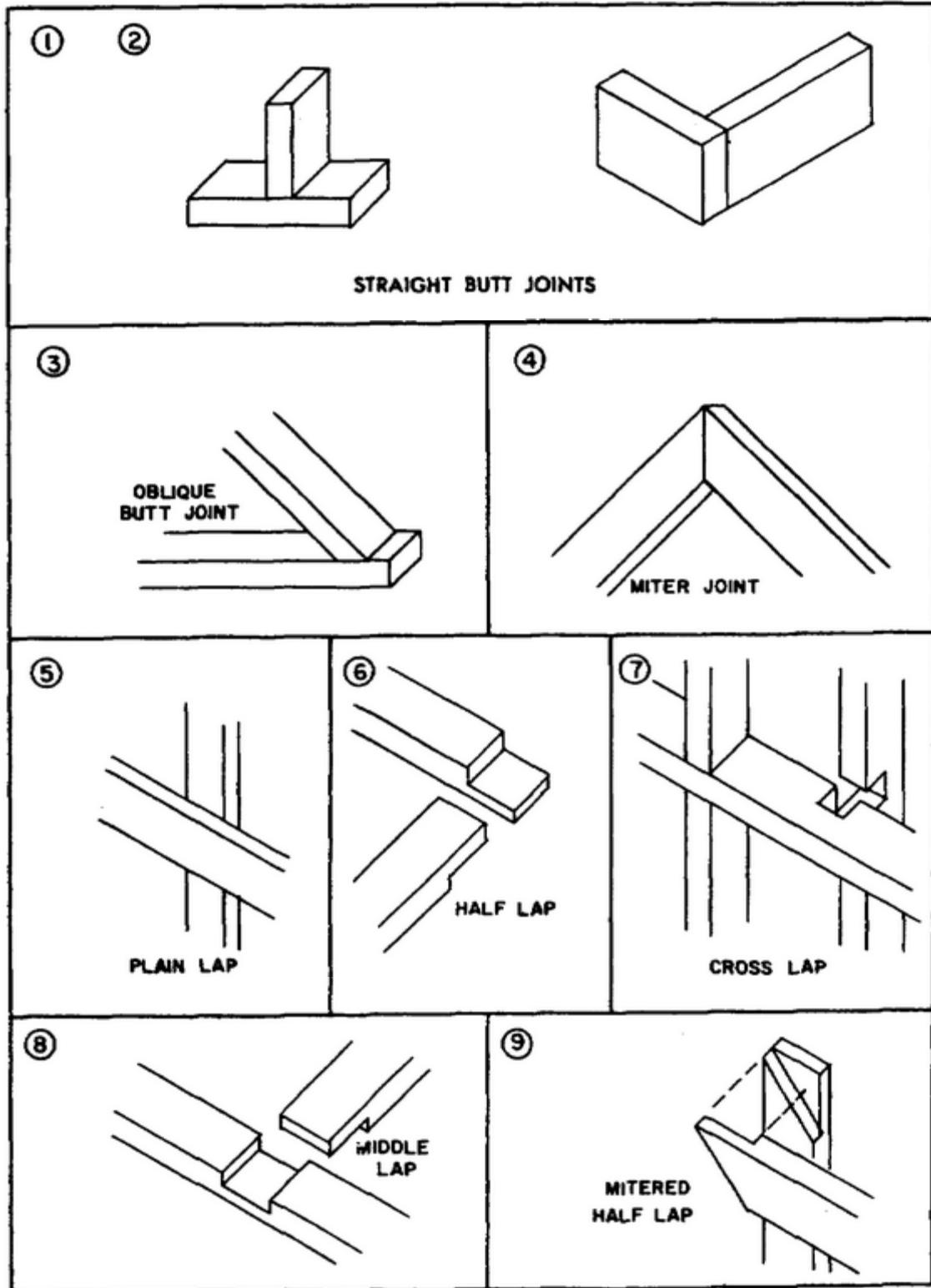


Figure 1-8. Butt and lap joints.

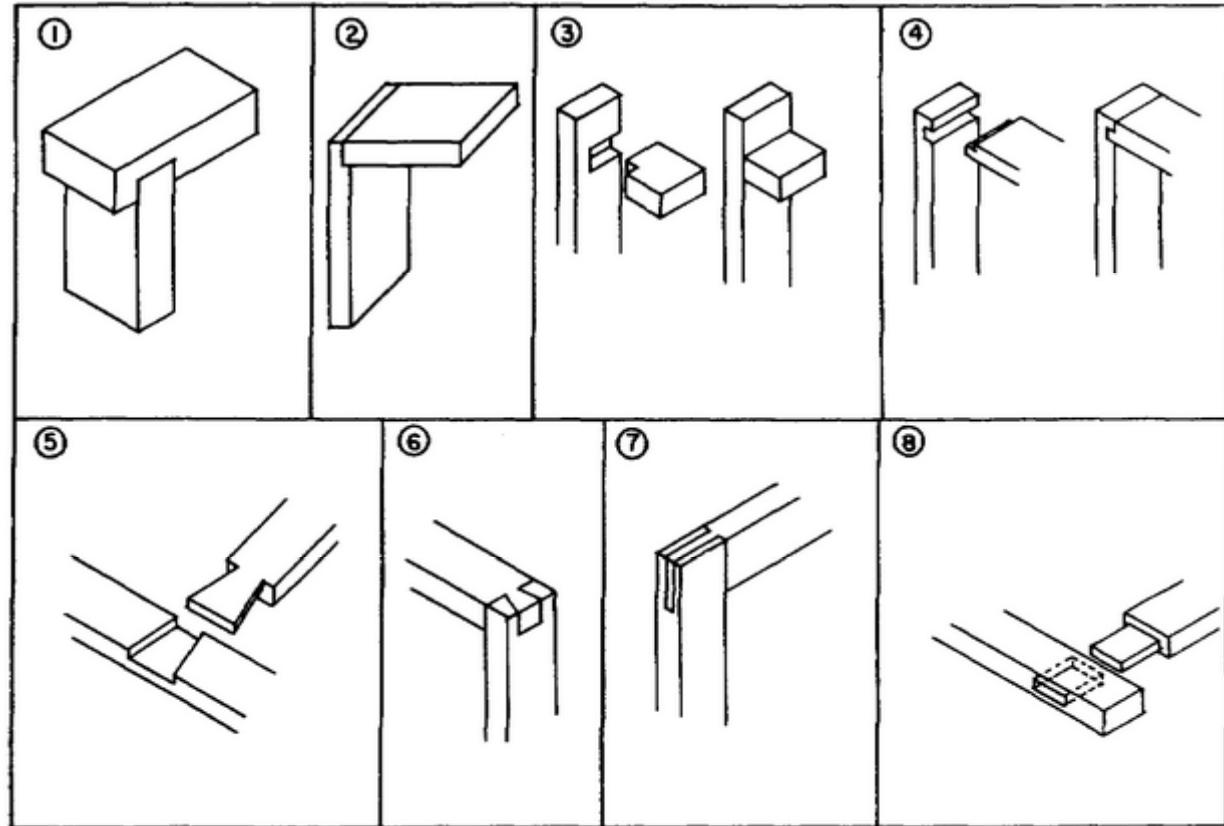


Figure 1-9. Dado, rabbet, dovetail, and mortise-and-tenon-joints.

1-9), and through mortise-and tenon (8, fig 1-9).

1-9. SPLICES

Splines are connections between two pieces that extend in the same line. The type of splice to use depends on the type or types of stress the spliced member must withstand. Members subject to longitudinal stress as vertical supports require splices designed to withstand compression (1, fig. 1-10). Members subject to transverse and angular stresses, such as braces, require splices designed to resist tension (2, fig. 1-10). Members used as horizontal supports, such as joists, require splices designed to resist bending (3, fig. 1-10).

a. Compression-resistant splices.

Compression splices are designed to support weight or exert pressure. The butt splice and the halved splice are the most common types.

(1) **Butt splice.** The butt splice is constructed by butting the squared ends of two pieces

together and securing them in this position by means of two wood scabs or metal plates (1, 2, fig. 1-11). Metal plates (fishplates) are fastened in place with bolts or screws. Bolts, screws, nails, or ring connectors may be used to secure scabs. Nails used with scabs should be staggered and driven at an angle. Too many nails or nails that are too large will weaken a splice.

(2) **Halved splice.** This splice is constructed by cutting away half the thickness for equal distances from the ends of two pieces and fitting the complementary tongues together (3, 1-11). The tongues should be long enough to provide adequate bearing surfaces. To give this splice some resistance to tension, fishplates or wooden scabs may be added as used with the butt splice.

(b. **Tension-resistant splices.** Tension members, such as certain truss elements and braces, undergo stress at the splice that is exerted in more than one direction (2, fig.

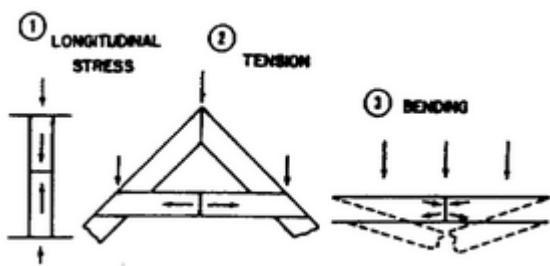


Figure 1-10. Splice stresses.

1-10). Tension splices are designed to provide increased bearing surface and additional shoulders within the splice to resist the buckling tension.

(1) **Square splice.** The square splice is a modification of the compression-resistant halved splice. Complementary notches are cut in the tongues to provide an additional locking shoulder (4, fig. 1-11). It may be greatly strengthened by adding fishplates or scabs.

(2) **Plain splice.** A hasty substitute for the square splice is the long plain splice (5, fig. 1-11). A long overlap of the two pieces is desirable to provide adequate bearing surfaces and room for enough nails or other fasteners to compensate for the lack of shoulder lock.

c. **Bend-resistant splices.** Horizontal timbers supporting weight are subject to compression of the upper side that has a tendency to crush the fibers, and to tension along the lower side that tends to pull the fibers apart as shown diagrammatically in 3, figure 1-10. The bend-resistant splice designed to meet these conditions is constructed by cutting oblique complementary tongues or laps in the ends of two pieces of timber (6, fig. 1-11). To absorb compression stress, the end of the upper tongue is cut square to butt against a corresponding square step or shoulder at the base of the complementary lower tongue. The end of the lower tongue is

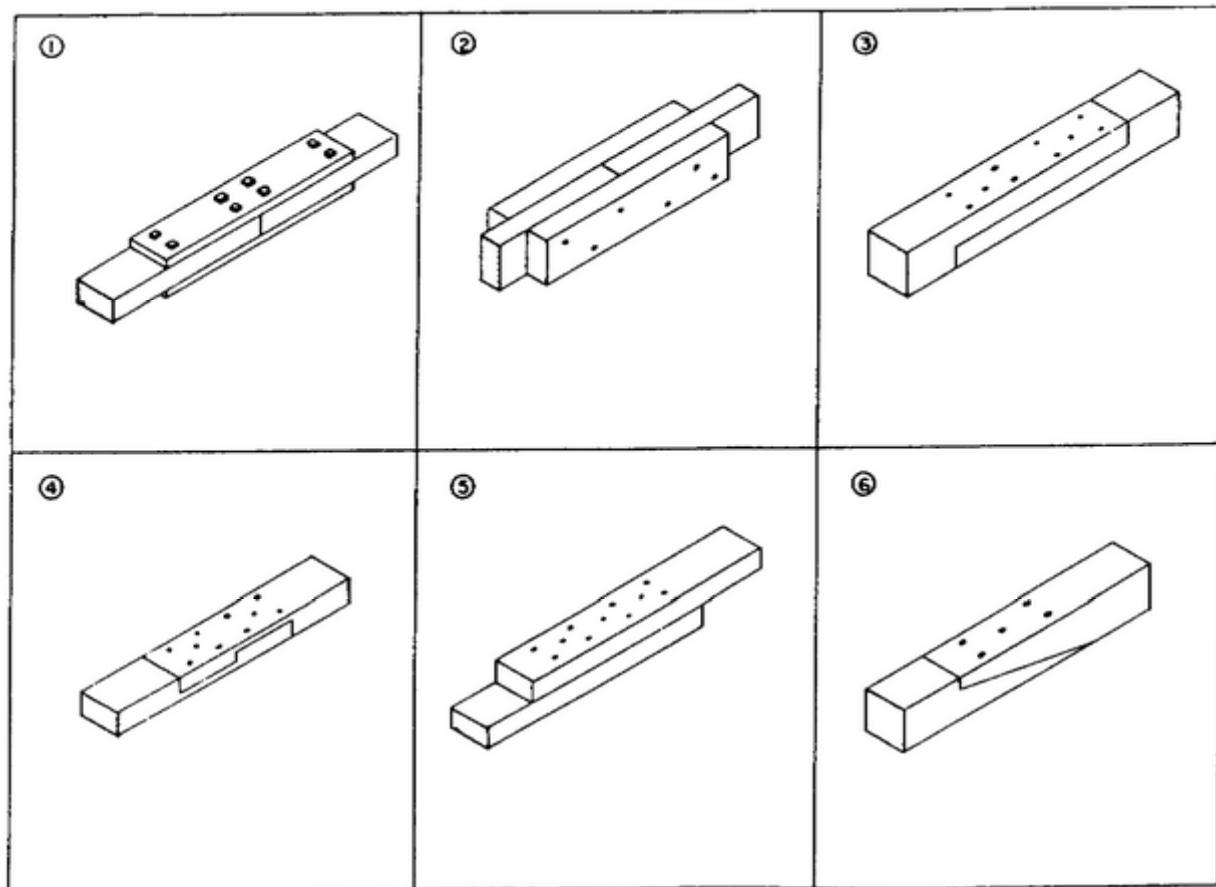


Figure 1-11. Compression, tension, and bending-resistant splices.

beveled or scarped to a thin edge since it will be subject to tension only. A fishplate or scab can be fastened along the bottom of the splice to resist the tendency of the pieces to separate there.

1-10. TYPES OF WOOD

A knowledge of the kinds and physical characteristics of wood will aid the engineer officer to correctly use this building material which is the basis of most TO construction. We may classify timber initially in four broad categories according to the nature of growth:

Deciduous - broad-leaved trees which shed leaves seasonally.

Coniferous - needle-leaved trees.

Bamboo.

Palm.

Figure 1-12 presents typical characteristics of wood and its uses.

a. Deciduous and coniferous trees are found in temperate climates and make good construction material. When cut into lumber, deciduous trees produce hardwoods and coniferous trees softwoods. Although no definite degree of hardness divides the two groups, woods in the hardwood category are of higher density than those classified as softwoods. Hardness is measured by the compression which a piece of timber can withstand when a weight is applied to it. Oak, maple, hickory, elm, beech, ash, and locust are representative hardwoods. Some of the more common softwoods are pine, fir, cedar, spruce, hemlock, cypress, larch, and redwood. In TO construction the Army uses mainly softwoods, principally because they are easier to work, lighter in weight per unit volume, less expensive, and, in general, more available.

b. Bamboo and palm trees are found in tropical climates, and in some respects are

HARDWOODS		SOFTWOODS GENERAL MILITARY CONSTRUCTION	
FLOORING	OAK HEAVY	YELLOW PINE (LONG LEAF)	HEAVY FRAMING
INTERIOR FINISH	STRONG HARD	HEAVY	DURABLE
HANDLES	HICKORY HEAVIEST	YELLOW PINE (SHORT LEAF)	SUBSTITUTE FOR LONG LEAF PINE
IMPLEMENT	HARDEST	VARIABLES	DURABLE
INTERIOR FINISH	MAPLE FINE GRAIN	DOUGLAS FIR STRONG	ALL TYPES OF CONSTRUCTION
HARD			DURABLE

Figure 1-12. Lumber and its uses.

better suited to construction than temperate climate trees. For example, they offer more resistance to insects and decay. Because of its shape - a thin hollow column - bamboo has been called the ideal building material. Lack of a simple method of satisfactorily connecting such members is its major short-coming. Both palm and bamboo have been used extensively by the Army.

1-11. SEASONING

Seasoning of lumber is the controlled drying or removal of moisture from wood. Seasoning increases the strength of timber, improves its resistance to decay, and minimizes shrinkage and warping of structural members. Since dry lumber is lighter, the dead weight of a structure is reduced by using seasoned timber. Although seasoned lumber is preferred for construction purposes, "green" timber may be used with good results for almost any TO type building. The only item for which green wood cannot be used satisfactorily in TO construction is sheathing. When green sheathing dries out after being covered with roll roofing, it shrinks and tears holes in the roofing material where the nails are inserted.

1-12. DEFECTS

In the growth and life of a tree certain defects occur which weaken timber cut from these trees. The defects are classed as heartshakes, windshakes, starshakes, knots, and checks.

a. Heartshake or heart rot. Heartshake is a defect of the heartwood found in older trees, especially the hemlock; it is seldom found in saplings. The heartshake is evidenced by a small round cavity at the center of the tree or timber. This cavity is caused by decay and results in cracks which extend outward to the bark (1, fig. 1-13).

b. Windshake. Windshake is the separation of the annual rings (2, fig. 1-13). This defect is most common in pine timber. Windshakes sometimes extend several feet up the trunk of a tree.

c. Starshake. A starshake is much like a heartshake in its effect. The difference between the two is that the starshake has no decay at the center. The cracks extend over the cross section of the log,

are wide in the center, and narrow to nothing near the bark. The wood along these cracks is solid (3, fig. 1-13).

d. Knots. Knots are irregular growths in the body of a tree which interrupt the smooth curve of the grain. The fibers of the tree are turned from their normal course and grow around the knot at that point of a tree where a limb is being formed. If the knot is large, cross grains are formed which cause the lumber to break easily (4, fig. 1-13).

e. Checks. Checks are splits in the outside part of a piece of timber which are caused by irregular shrinkage. Checks are formed when the circumference shrinks more than the interior section of the wood (5, 6, fig. 1-13).

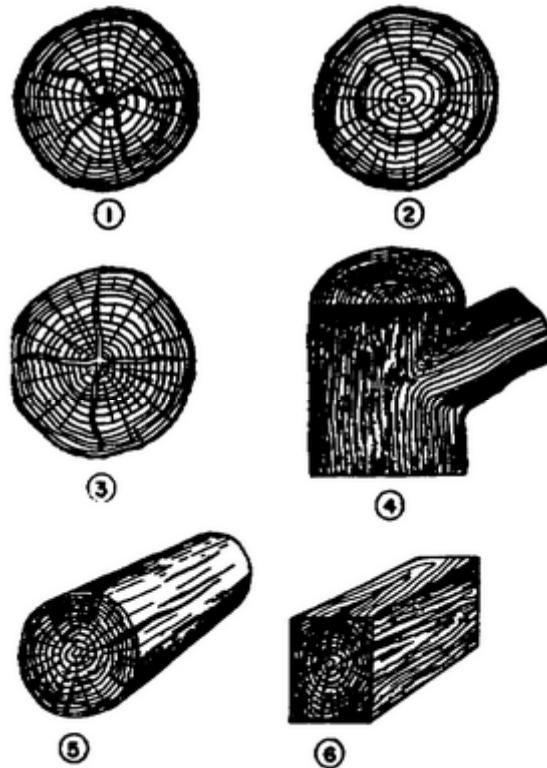


Figure 1-13. Defects in timber.

1-13. CAUSES OF DECAY

There are several types of decay which render lumber unserviceable: dry rot, wet rot, and common rot.

a. Dry rot. Dry rot is the most common and the most dangerous. It is a disease which spreads from one part of the wood to another, causing the wood to lose its strength and cohesive power and eventually to decay altogether. Dry rot occurs most often where timber is kept alternately wet and dry, or where there is no ventilation. The rot occurs on the inside of timber and leaves a shell on the outside; the inner part becomes soft and powderlike and is generally invisible due to the outer shell.

b. Wet rot. Wet rot occurs in growing trees and is similar to dry rot. It occurs when the wood becomes saturated with water which it absorbs from a swamp or bog. It may be readily communicated from one piece of wood to another by contact.

c. Common rot. Common rot is manifested by the presence of external yellow spots on the ends of timber or by a yellowish dust in the checks and cracks, especially where the pieces are in contact with one another. This is caused by improper ventilation of wood-storage sheds and lumber piles. It is easily remedied by proper stacking and ventilation.

1-14. DESTRUCTION BY INSECTS

Although decay is the principal cause of deterioration, a great deal of damage can be done by certain insects. The most common land varieties of destructive insects are the powder post, the pole borer, and the termite. The most common water type is the marine borer.

a. Powder post. The powder post develops very rapidly. It bores into the wood and transforms it into a fine powder. Since the powder post lodges initially under the bark, all bark should be removed from air-dried lumber before it is used in buildings.

b. Pole borer. The pole borer attacks timber that is somewhat damp and transforms it into reddish-brown dust. It will not attack water-soaked timber, but it will attack dry timber, either sound or decayed.

c. Termite. Termites are not true ants although they look much like them and live like them, in large colonies. The winged male and female may be seen "swarming" in the spring or fall on their way to start new colonies. Otherwise they are very seldom seen, as they stay in the earth or in wood. They damage rafters, joists, beams, or other timber of buildings; the inside may be entirely eaten out before the damage is noticed since termites leave an outer shell of wood.

d. Marine borer.

(1) Timber placed in water is subject to attack by two classes of marine borers, the mollusk and crustacean type.

(2) The destructive mollusk is a worm, sometimes called the navalis, teredo, or shipworm. It has a head equipped with a shell-like substance shaped like an auger by means of which it bores its way into timber. It has been known to grow to sizes of 1/4 to 1/2 inch in diameter and from 1 1/2 to 3 feet in length. It may ruin timber in less than a year. This marine borer prefers clear salty water. It operates against timber set between the mean tide and low water mark and about a foot above the mud line.

(3) The wood louse is a member of the crustacean family. It grows to the size of a grain of rice and bores into wood by means of sharp jaws. It is active only in clear still water and confines itself to a belt or line around the low water line. Wood lice can destroy piling within a year's time in heavily infested areas.

1-15. STANDARD SIZES OF LUMBER

Lumber is usually sawed into standard sizes of length, width, and thickness. This permits uniformity in planning structures and in ordering materials. Table 1-1 lists some nominal and minimum-dressed sizes for dry, softwood lumber as set forth in the American Softwood Lumber Standard, Voluntary Product Standard 20-70. Dry lumber, in this instance, is defined as lumber which has been seasoned to a moisture content of 19 percent or less. Lumber having a moisture content in excess of 19 percent is called green lumber and the dressed dimensions may be slightly

TABLE 1-1. *Nominal Sizes and Dressed Sizes of Lumber (New Standard)*

Nominal size (in.)	Dressed size (in.)
1 x 3 -----	¾ x 2½
1 x 4 -----	¾ x 3½
1 x 6 -----	¾ x 5½
1 x 8 -----	¾ x 7½
1 x 10 -----	¾ x 9½
1 x 12 -----	¾ x 11½
2 x 4 -----	1½ x 3½
2 x 6 -----	1½ x 5½
2 x 8 -----	1½ x 7½
2 x 10 -----	1½ x 9½
2 x 12 -----	1½ x 11½
3 x 8 -----	2½ x 7½
3 x 10 -----	2½ x 9½
3 x 12 -----	2½ x 11½
4 x 12 -----	3½ x 11½
4 x 16 -----	3½ x 15½
6 x 12 -----	5½ x 11½
6 x 16 -----	5½ x 15½
6 x 18 -----	5½ x 17½
8 x 16 -----	7½ x 15½
8 x 20 -----	7½ x 19½
8 x 24 -----	7½ x 23½

greater. Table 1-2 gives the nominal and dressed sizes that were in use prior to adoption of the standards indicated in table 1-1. Lumber dressed to the dimensions shown in table 1-2 may still appear in some areas and certainly lumber of both finished dimensions will be used and the dimensions must be given consideration in repair and modification work involving existing framed structures.

1-16. GRADES OF LUMBER

Lumber as it comes from the sawmill is divided into three main classes: yard lumber, structural material, and factory and shop lumber. In keeping with the purpose of this subcourse, only yard lumber will be considered. Yard lumber is manufactured and classified, on a quality basis, into those sizes, shapes, and qualities required for ordinary construction and general building purposes including TO construction. It is subdivided into classifications of select lumber and common lumber.

TABLE 1-2. *Nominal Sizes and Dressed Sizes of Lumber (Old Standard)*

Nominal size (in.)	Dressed size (in.)
1 x 3 -----	25/32 x 2½
1 x 4 -----	25/32 x 3½
1 x 6 -----	25/32 x 5½
1 x 8 -----	25/32 x 7½
1 x 10 -----	25/32 x 9½
1 x 12 -----	25/32 x 11½
2 x 4 -----	1½ x 3½
2 x 6 -----	1½ x 5½
2 x 8 -----	1½ x 7½
2 x 10 -----	1½ x 9½
2 x 12 -----	1½ x 11½
3 x 8 -----	2½ x 7½
3 x 10 -----	2½ x 9½
3 x 12 -----	2½ x 11½
4 x 12 -----	3½ x 11½
4 x 16 -----	3½ x 15½
6 x 12 -----	5½ x 11½
6 x 16 -----	5½ x 15½
6 x 18 -----	5½ x 17½
8 x 16 -----	7½ x 15½
8 x 20 -----	7½ x 19½
8 x 24 -----	7½ x 23½

a. **Select lumber.** Select lumber is of good appearance and finish, and is identified by the following grades:

(1) **Grade A.** Grade A is suitable for natural finishes and practically clear.

(2) **Grade B.** Grade B is suitable for natural finishes, of high quality, and generally clear.

(3) **Grade C.** Grade C is adapted to high quality paint finishes.

(4) **Grade D.** Grade D is suitable for paint finishes between higher finishing grades and common grades, and contains somewhat the nature of both.

b. **Common lumber.** Common lumber is suitable for general construction and utility purposes and is identified by the following grade names:

(1) **No. 1 common.** No. 1 common is suitable for use without waste; it is sound and tight-knotted; and it may be considered watertight lumber.

(2) No. 2 common. No. 2 common is less restricted in quality than No. 1 but of the same general quality. It is used for framing, sheathing, and other structural forms where the stress or strain is not excessive.

(3) No. 3 common. No. 3 common permit some waste with prevailing grade characteristics larger than in No. 2. It is used for such rough work as footings, guardrails, and rough flooring.

(4) No. 4 common. No. 4 common permits waste and is of low quality, admitting the coarsest features, such as decay and holes. It is used for sheathing, subfloors, and roof boards in the cheaper types of construction, but the most important industrial outlet is for boxes and crates.

c. **TO construction grades.** Most of the softwood lumber purchased by the Army for TO construction is common stock, Nos. 1 or 2.

1-17. LENGTHS AND DRESSING

a. Standard lengths of lumber range from 8 to 20 feet by 2-foot increments.

b. For a list of standard thickness and widths of lumber useful for military construction turn

1-18. BOARD MEASURE

a. The unit of measurement of lumber is the board foot. By definition a board foot is the volume of a board 1 inch thick, 1 foot wide, and 1 foot long. BF, bf, BFM, bfm are all commonly employed abbreviations for board foot. M in front of the abbreviation stands for 1000 board feet. Thus, 4 MBF would indicate 4000 board feet.

b. From the definition above the following formulas are derived:

$$BF = \text{thickness in inches} \times \text{width in feet} \times \text{length in feet}$$

or

$$BF = \frac{\text{thickness in inches} \times \text{width in inches} \times \text{length in feet}}{12}$$

or

$$BF = \frac{\text{thickness in inches} \times \text{width in inches} \times \text{length in inches}}{144}$$

c. Table 1-3 gives the content in board feet of common sizes and lengths of lumber used in TO construction.

1-19. METHODS OF FASTENING

Wood fasteners used in the theater of operations are made of metal. These may be classified as nails, screws, bolts, driftpins, corrugated fasteners, and timber connectors.

to tables 1-1 and 1-2. Note that both a nominal and an actual size is given for each item in both tables. The nominal size represents the dimensions of the rough lumber, but the actual size is smaller due to the smoothing or "dressing" of the sides and/or edges. During this surfacing process, from 1/4 to 3/4 inch, depending on the size of the lumber, is removed from the edges and sides. Abbreviations are sometimes used to show how many sides or edges have been surfaced.

c. The following tabulation explains the abbreviations commonly used to indicate the amount of surfacing lumber has received.

S & E	.....	side and edge
S1E	.....	surfaced one edge
S1S1E	.....	surfaced one side and one edge
S1S2E	.....	surfaced one side and two edges
S2E	.....	surfaced two edges
S4S	.....	surfaced four sides

1-20. NAILS

General. The standard nail used by the Army carpenter is the wire nail, so called because it is made from steel wire. There are many types of nails, all of which are classified

TABLE 1-3. *Contents of Lumber (Number of Board Feet in Various Sizes for Lengths Given)*

Size of piece (in.)	Length of piece (ft)									
	8	10	12	14	16	18	20	22	24	
2 x 4	5 1/3	6 2/3	8	9 1/3	10 2/3	12	13 1/3	14 2/3	16	
2 x 6	8	10	12	14	16	18	20	22	24	
2 x 8	10 2/3	13 1/3	16	18 1/3	21 1/3	24	26 2/3	29 1/3	32	
2 x 10	13 1/3	16 2/3	20	23 1/3	26 2/3	30	33 1/3	36 2/3	40	
2 x 12	16	20	24	28	32	36	40	44	48	

according to use and form. The wire nail is round-shafted, straight, pointed, and may vary in size, weight, size and shape of head, type of point, and finish. All normal requirements of construction and framing are filled by one of the nail types described below. There are a few general rules to be followed in the use of nails in carpentry. Nails should be driven at an angle slightly toward each other and should be carefully placed to provide the greatest holding power. Nails driven with the grain do not hold as well as nails driven across the grain. A few nails of proper type and size, properly placed and properly driven, will hold better than a great many driven close together. Nails can generally be considered the cheapest and easiest fasteners to be applied. In terms of holding power alone, nails provide the least, screws of comparable size provide more, and bolts provide the greatest amount.

b. Types of nails.

(1) **Common wire nails.** Common wire nails and box nails are similar except box nails are sized smaller than common nail. The common wire nail (1, fig. 1-14) is used for housing-construction framing. The common wire nail and the box nail are generally used for structural carpentry.

(2) **Finishing nails (2, fig. 1-14).** The finishing nail is made from finer wire and has a smaller head than the common nail. It may be set below the surface of the wood into which it is driven and will leave only a small hole, easily puttied up. It is generally used for interior or exterior finishing work and is used for finished carpentry and cabinet making.

(3) **Scaffold or form nails (3, fig. 1-14).** The scaffold, form, or staging nail (as it is sometimes called) is made with what may appear to be two heads. The lower head, or shoulder, is provided so that the nail may be driven securely home to give maximum holding power while the upper head projects above the surface of the wood to make its withdrawal simple. The reason for this design is that the scaffold nail is not meant to be permanent. It is used in the construction of temporary structures such as scaffolding and staging and is classified for temporary construction.

(4) **Roofing nails (4, fig. 1-14).** Roofing nails are round-shafted, diamond-pointed, galvanized nails of relatively short length and comparatively large heads. They are designed for fastening flexible roofing materials and for resisting continuous exposure to weather. Several general rules apply to the use of roofing nails, especially their use with asphalt shingles. If shingles or roll roofing is being

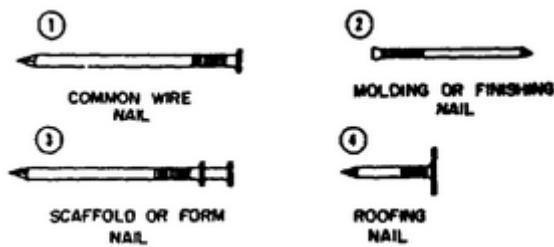


Figure 1-14. *Types of nails.*

applied over old roofing, the roofing nails selected must be of sufficient length to go through the old material and secure the new. Asphalt roofing material is fastened with corrosion resistant nails, never with plain nails. Nailing is begun in the center of the shingle, just above the cutouts or slots, to avoid buckling.

c. **Sizes and uses of nails.** Nail sizes are designated by the use of the term "penny". This term

designates the length of the nail (1-penny, 2-penny, etc.), which is the same for all types. The approximate number of nails per pound varies according to the type and size. The wire gage number varies according to type. Figure 1-15 provides the information implicit in the term "penny" for each of the type of nails referred to in this section. The "d" adjacent to the numbers in the "Size" column is the accepted abbreviation of the

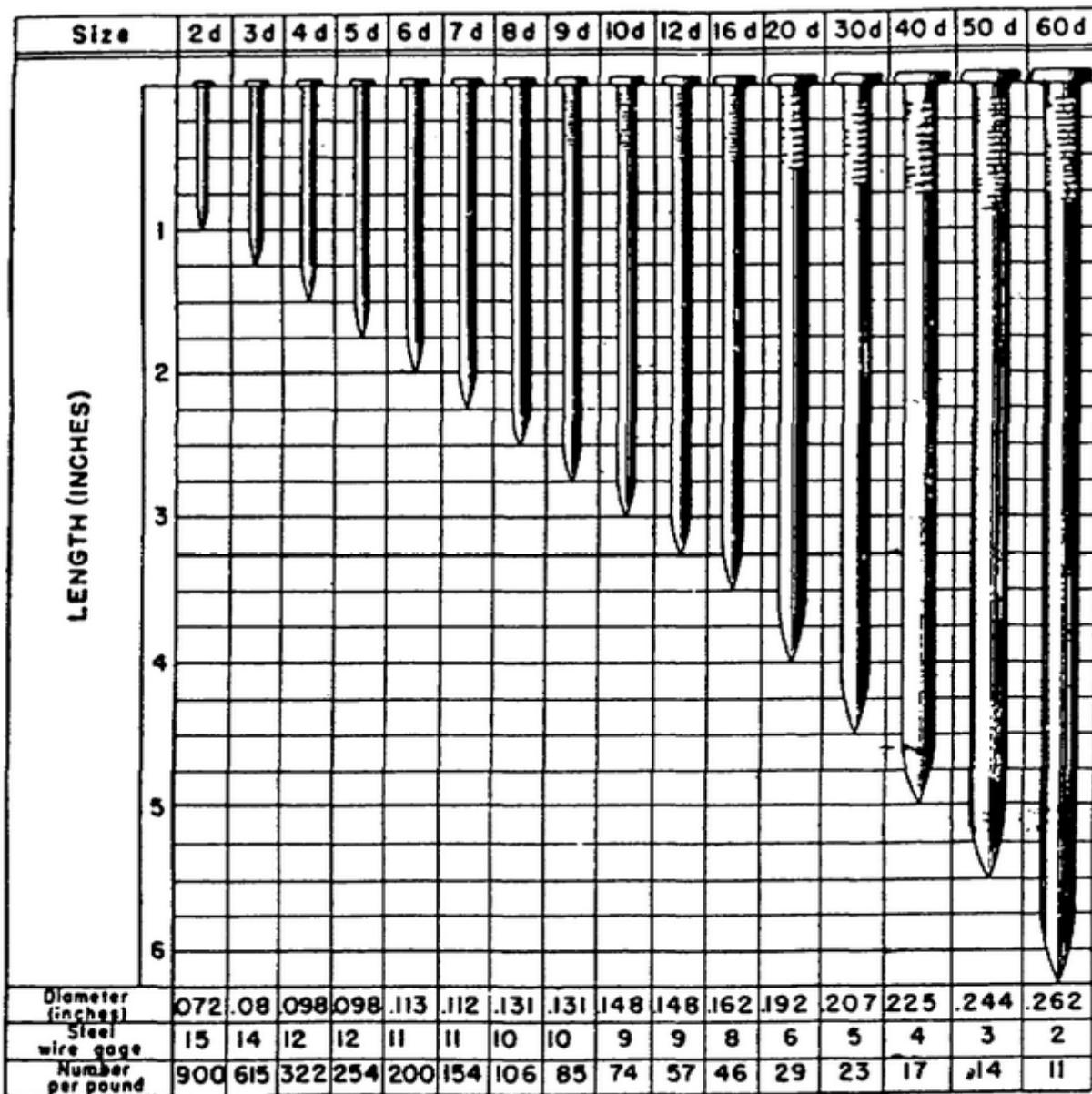


Figure 1-15. Nail lengths.

word "penny". Table 1-4 lists the kinds and quantities of nails required for building frame structures.

1-21. SCREWS

The use of screws instead of nails may be dictated by a number of factors, including the type of

material that is to be fastened, the need for greater holding power, the desire for a better finished appearance, and limitations on the number of fasteners that can be used. Screws can also be withdrawn easily without damage to the material. Wood screws are usually made of unhardened steel but some

TABLE 1-4. *Wire Nails - Kinds and Quantities Required*

Sizes and Kinds of Material	Sizes	Length in inches	Approx. no. per lbs.	Pounds per Mbf on center as follows:			
				12"	16"	36"	48"
1 x 4	8d common	2 1/2	106	60	48	23	20
1 x 6	8d common	2 1/2	106	60	32	16	15
1 x 8	8d common	2 1/2	106	31	27	12	10
1 x 10	8d common	2 1/2	106	25	20	10	8
1 x 12 Used square edges, as platforms, floors, sheathing, or shiplap. When used dressed and notched, blind nailed, only 1/2 quantity named required.	8d common	2 1/2	106	31	24	12	10
2 x 4	20d common	4	29	105	80	60	33
2 x 6	20d common	4	29	70	54	27	22
2 x 8	20d common	4	29	53	40	21	17
2 x 10 notched, blind nailed, only 1/2 quantity named required.	20d common	4	29	60	50	25	20
2 x 12	20d common	4	29	52	41	21	17
3 x 4	60d common	6	11	197	150	76	61
3 x 6	60d common	6	11	131	97	52	42
3 x 8	60d common	6	11	100	76	38	34
3 x 10	60d common	6	11	178	137	70	55
3 x 12	60d common	6	11	145	115	53	46
Base, per 100 ft. lin.							
Ceiling, 3/4 x 4	8d finish	2 1/2	189	---	1	--	--
Ceiling, 1/2 and 5/8	8d finish	2 1/2	189	18	14	--	--
Finish, 7/8	8d finish	2	309	11	8	--	--
Finish, 1 1/8	10d finish	3	189	25	12	--	--
Flooring, 1 x 3	8d floor brads	2 1/2	99	42	32	--	--
Flooring, 1 x 4	8d floor brads	2 1/2	99	32	26	--	--
Flooring, 1 x 6	8d floor brads	2 1/2	99	22	18	--	--
Framing, 2 x 4 to 2 x 16 requires 3 or more sizes and very greatly	20d common	4	29	20	16	--	--
Framing, 3 x 4 to 3 x 14	16d common	3 1/2	46	10	10	--	--
Siding, drop, 1 x 4	10d common	3	74	8	6	--	--
Siding, drop, 1 x 6	60d common	6	11	30	25	--	--
Siding, drop, 1 x 8	8d casing	2 1/2	145	45	35	--	--
Siding, bevel, 1/2 x 4	8d finish	2	309	23	18	--	--
Siding, bevel, 1/2 x 6	8d finish	2	309	15	13	--	--
Siding, bevel, 1/2 x 8	8d finish	2	309	12	10	--	--
Casing, per opening	6d and 8d casing			About 1/2 pound per side.			
Flooring, 3/8 x 2	3d brads	1 1/4	568	About 10 pounds per 1000 square feet. (12" o.c.)			
Lath, 48"	3d fine	1 1/8	778	6 pounds per 1000 pieces. (16" o.c.)			
Ready roofing	Barbed roofing	7/8	469	3/4 of a pound to the square. (2" o.c.)			
Ready roofing (5/8 heads)	American felt roofing	7/8	180	1 1/2 pounds to the square. (2" o.c.)			
Shingles*	3d shingle	1 1/4	420	4 1/2 pounds; about 2 nails to each 4 inches.			
Shingles	4d shingle	1 1/2	274	7 1/2 pounds; about 2 nails to each 4 inches.			
Shingles	American felt roofing	7/8	180	12 lbs, 5/8" heads; 4 nails to shingle.			
Shingles wall board, around entire edge	Barbed roofing 2d Barbed Bury, flat head	7/8	469	6 1/2 lbs, 5/8" heads; 4 nails to shingle.			
Wall board, intermediate nailings	2d casing or floor brad	1	1150	5 pounds, 5/8" heads; per 1000 square feet.			
		1	1010	2 1/2 lbs, 5/8" heads; per 1000 square feet.			

*Wood shingles vary in width; asphalt are usually 8 inches wide. Regardless of width 1000 shingles are the equivalent of 1000 pieces 4 inches wide.

special-purpose screws are made of brass, aluminum, or stainless steel. Ordinary soft-steel screws may be bright finished or blued or they may be zinc, cadmium, brass, or chrome plated. Wood screws have gimlet points and are threaded for approximately two-thirds of their length.

a. Types of wood screws. Wood screws are designated according to head styles as shown in figure 1-16. The types commonly used in construction are: slotted flathead, oval head, round head, and Phillips head. To prepare wood for screws, as shown in figure 1-17, bore a pilot or body hole the diameter of the screw that is to be used through the piece of wood that is to be fastened on. Then bore a smaller starter or lead hold in the piece that is to be fastened to, to avoid hard turning and the possibility of splitting the wood. If flatheaded screws are to be used the pilot or body hole should be countersunk.

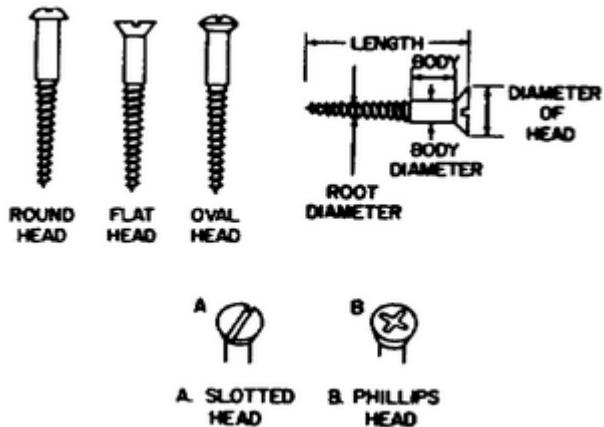


Figure 1-16. Types of wood screws.

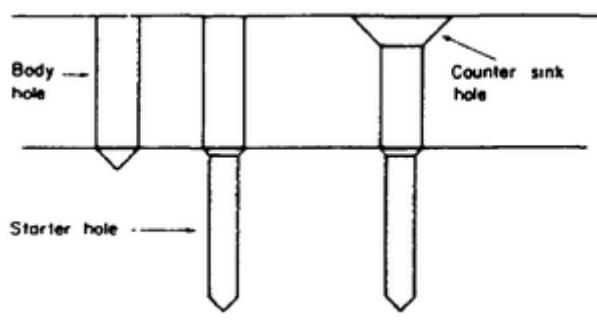


Figure 1-17. Method of preparing wood for screws.

b. Screw sizes. Wood screws vary in length from 1/4 inch to 6 inches. Screws up to 1 inch in length increase by eighths of an inch; screws from 1 to 3 inches by quarter inches, and screws from 3 to 5 inches by half inches. There are also 6-inch screws. Each length is made in a number of shaft sizes indicated by an arbitrary number that represents no particular measurement but indicates relative diameters. Tables 1-5 and 1-6 provide size, length, gage, and applicable drill and bit sizes for screws.

c. Lag screws. The proper name for lag screws in the nomenclature of the Army supply system is bolt, lag, wood-screw type. These screws are sometimes required in frame construction. They are longer and much thicker bodied than common wood screws and have coarser threads which extend from a cone or gimlet point slightly more than half the length of the screw. Both square- and hexagon-headed lag screws are usually driven by a wrench. Combined with expansion shields or anchors they are used to attach timbers to existing masonry.

d. Expansion shields. Expansion shields, or anchors as they are sometimes called, are inserted in a predrilled hole. After the expansion shield is inserted, the bolt or occasionally another type of fastener such as a screw or even a nail is driven into the shield, causing it to expand and become firmly wedged in place (fig. 1-18).

1-22. BOLTS

a. General. Bolts are used in construction when great strength is required or when the work under construction must be frequently disassembled. Their use usually requires nuts for fastening and washers to protect the surface of the material to be fastened. Bolts are selected according to specific requirements in terms of length, diameter, threads, style of head, and type. Proper selection of head style and type of bolt will result in good appearance as well as good construction. The use of washers underneath the nut or underneath both the nut and the bolt head will avoid marring wood surfaces and permit additional torque in tightening.

TABLE 1-5. Screw Sizes and Dimensions

Length (inches)	Size numbers																								
	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	22	24	26	28	30
.4	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x
.5	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x
.6	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x
.7	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x
.8	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x
.9	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x
1.0	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x
1.1	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x
1.2	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x
1.3	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x
1.4	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x
1.5	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x
1.6	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x
1.7	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x
1.8	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x
1.9	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x
2.0	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x
2.1	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x
2.2	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x
2.3	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x
2.4	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x
2.5	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x
2.6	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x
2.7	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x
2.8	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x
2.9	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x
3.0	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x
3.1	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x
3.2	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x
3.3	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x
3.4	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x
3.5	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x
3.6	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x
3.7	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x
3.8	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x
3.9	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x
4.0	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x
4.1	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x
4.2	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x
4.3	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x
4.4	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x
4.5	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x
4.6	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x
4.7	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x
4.8	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x
4.9	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x
5.0	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x
5.1	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x
5.2	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x
5.3	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x
5.4	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x
5.5	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x
5.6	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x
5.7	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x
5.8	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x
5.9	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x
6.0	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x

TABLE 1-6. Drill and Auger Bit Sizes or Wood Screws

Screw-size No.	1	2	3	4	5	6	7	8	9	10	12	14	16	18
Nominal screw body diameter	.073	.086	.099	.112	.125	.138	.151	.164	.177	.190	.216	.242	.268	.294
Body Hole Drill size	5 64	3 32	3 32	7 64	1 8	9 64	5 32	11 64	11 64	3 16	7 32	15 64	17 64	19 64
Starter Hole Bit size	1 16	1 16	5 64	5 64	3 32	7 64	7 64	1 8	1 8	9 64	5 32	3 16	13 64	4

b. Type of bolts (fig. 1-19).

(1) **Carriage bolts.** Carriage bolts fall into three categories within the Army supply system: bolt, finned neck; bolt, ribbed neck; and bolt, square neck. These bolts have round heads that are not designed to be wrench driven. They are threaded only part of the way up the shaft; usually the threads

are two to four times the diameter of the bolt in length. In each type of carriage bolt the upper part of the shank, immediately below the head, is designed to grip the material in which the bolt is inserted and keep the bolt from turning when a nut is tightened down on it and/or removed. The finned type is designed with two or more fins extending

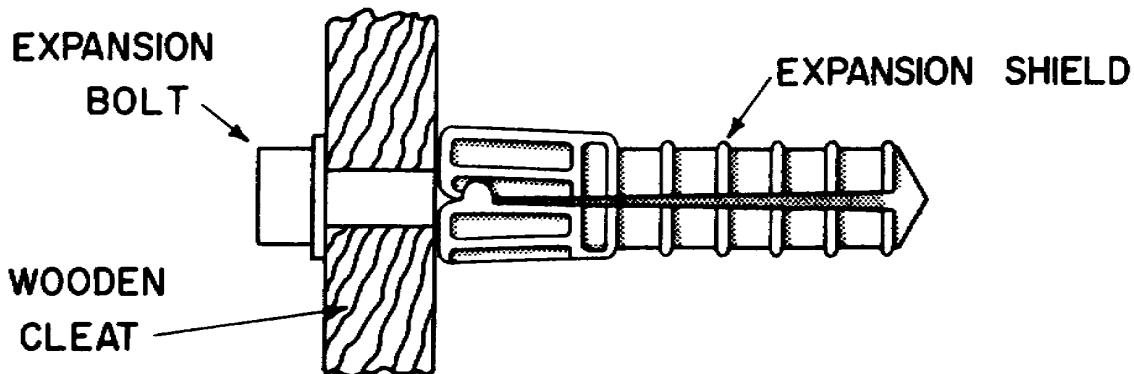


Figure 1-18. Bolt with expansion shield.

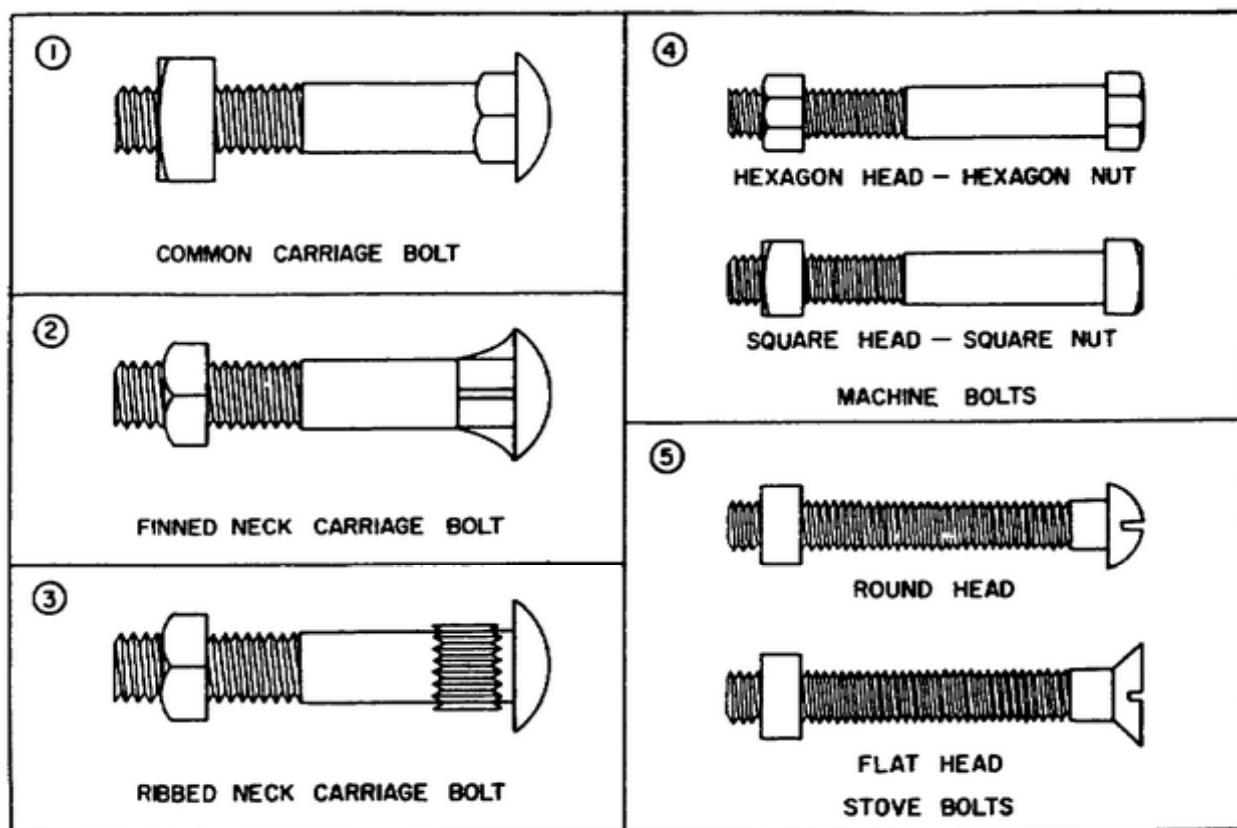


Figure 1-19. Types of bolts.

from the head to the shank. The ribbed type is designed with longitudinal ribs, splines, or serrations on all or part of a shoulder located immediately beneath the head. The square-neck bolt is designed with a square or rectangular shoulder immediately beneath the head. Holes to receive carriage bolts are bored to a tight fit of the body of the bolt and

counterbored to permit the head of the bolt to fit flush with, or below the surface of, the material being fastened. The bolt is then driven through the hole with a hammer. Carriage bolts are chiefly for wood-to-wood application but may also be used for wood-to-

metal applications. If used for wood to metal application, the head should be fitted to the wood members. Metal surfaces are sometimes predrilled and countersunk to permit the use of carriage bolts metal to metal. Carriage bolts can be obtained from 1/4 inch diameter to 1 inch diameter, and up to 20 inches long. A common flat washer should be used with carriage bolts between the nut and the wood surface.

(2) Machine bolts. Machine bolts are made with cut National Fine or National Coarse threads extending in length from twice the diameter of the bolts plus 1/4 inch (for bolts less than 6 inches in length) to twice the diameter of the bolt plus 1/2 inch (for bolts more than 6 inches in length). They are precision made and generally applied metal to metal where close tolerance is desirable. The head may be square, hexagon, double hexagon, rounded, or flat countersunk. The nut usually corresponds in shape to the head of the bolt with which it is used. Machine bolts are not slotted for screwdrivers. Selection of the proper machine bolt is made on the basis of head style, length, diameter, number of threads per inch, and coarseness of thread. The hole through which the bolt is to pass is bored to the same diameter as the bolt and may, in some cases, be slightly larger. Machine bolts are made in diameters from 1/4 inch to 3 inches and may be obtained in any length desired.

(3) Stove bolts. Stove bolts are less precisely made than machine bolts. They are made with either flat or round slotted heads and may have threads extending over the full length of the body, over part of the body, or over most of the body. They are generally used with square nuts and applied metal to metal, wood to wood, or wood to metal. If flat headed, they are countersunk; if round headed, they are drawn flush to the surface. Either type may be driven with a screwdriver, or may be held with a screwdriver while a wrench is used on the nut.

1-23. DRIFTPINS (fig. 1-20)

Driftpins, sometimes called driftbolts, are long, heavy threadless pins used to hold heavy pieces of timber together. Driftpins have heads and vary in

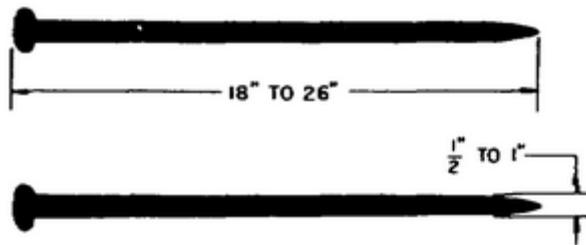


Figure 1-20. Driftpins (driftbolts).

diameter from 1/2 to 1 inch, and in length from 18 to 26 inches. To use a driftpin, a hole slightly smaller than the diameter of the pin is made in the timber. The pin is driven into the hole and held in place by the compressive action of the wood fibers.

1-24. CORRUGATED FASTENERS

a. General. Corrugated fasteners are one of the many means by which joints and splices are fastened in small timber and boards. They are used particularly to strengthen miter joints. Corrugated fasteners are normally made of sheet metal of 18 to 22 gage with alternate ridges and grooves. The ridges vary from 3/16 to 5/16 inch, center to center. One end is cut square; the other end is sharpened with beveled edges.

b. Types. There are two types of corrugated fasteners: one with the ridges running parallel (1, fig. 1-21), the other with ridges running at a slight angle to one another (2, fig. 1-21). The latter type has a tendency to compress the material since the ridges and grooves are closer at the top than at the bottom.

c. Size. These fasteners are made in several different lengths and widths. The width varies from 5/8 to 1-1/8 inches, while the length varies from 1/4 to 3/4 inch. The fasteners are also made with different numbers of ridges, ranging from three to six ridges per fastener.

d. Use. Corrugated fasteners are used in a number of ways: to fasten parallel boards together, such as in fashioning table tops; to make any type of joint; and to replace nails when nails might split the timber. The fasteners have a greater holding power than

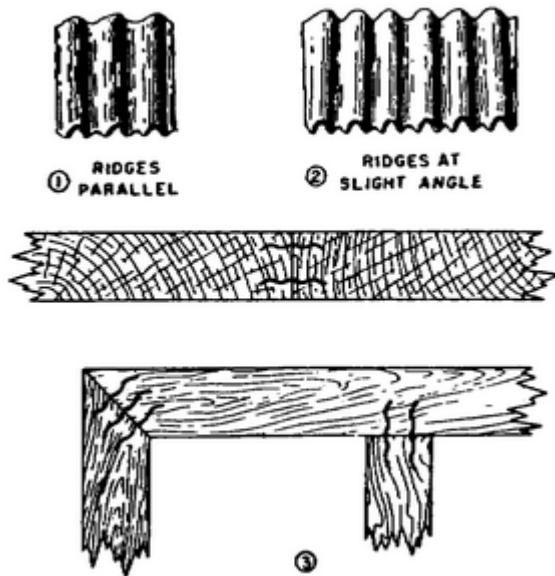


Figure 1-21. Corrugated fasteners and their uses.

nails in small timber. 3, figure 1-21 shows the proper method of inserting the fasteners.

1-25. TIMBER CONNECTORS

a. **General.** Timber connectors are metal devices used for increasing the joint strength in timber structures. Efficient connections for either timber-to-timber joints or timber-to-steel joints are provided by the several types of timber connectors. The appropriate type for a specific structure is determined primarily by the kind of joint to be made and the load to be carried. These connectors eliminate much complicated framing of joints. Some of the important advantages are that they simplify the design of heavy construction provide greater efficiency of material, reduce the amount of timber and hardware used, and save time and labor. Many types are used; however, the most common are split rings and toothed rings.

b. Types and uses.

(1) **Split rings.** Split rings are made of low-carbon steel in sizes of 2 1/2- and 4-inch diameters. They are used between two timber faces for heavy construction. They fit into grooves which are cut half the depth of the ring into each of the

timber faces. (fig. 1-22). The grooves are made with a special bit used in an electric, air, or hand drill. The tongue-and-groove split in the ring permits simultaneous ring bearing against the cone wall and outer wall of the groove into which the ring is placed. The inside bevel and mill edge facilitates installation into and removal from the groove.

(2) **Toothed rings.** Toothed rings are corrugated and toothed on both edges and are made from 16-gage-plate low-carbon steel (fig. 1-23). They are used between two timber framing members in comparatively light construction and are embedded into the contact faces of the joint members by means of pressure.

1-26. EXCAVATIONS

In the theater of operations, there is little excavation for building, but any excavating that is done requires a set procedure. In excavating for a building with earth floors, all that is necessary is a small trench to contain the sill (fig. 1-24). The building may then be constructed and the grading on the inside done later, if necessary. In small buildings where there are no wood floors, the earth should be thrown on the inside to raise the

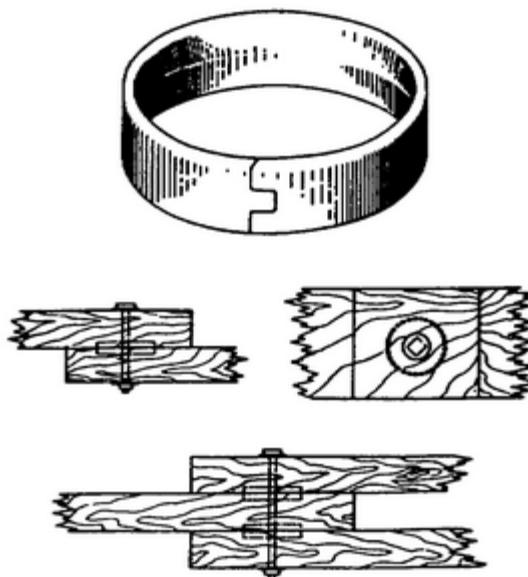


Figure 1-22. Split ring and its installation.

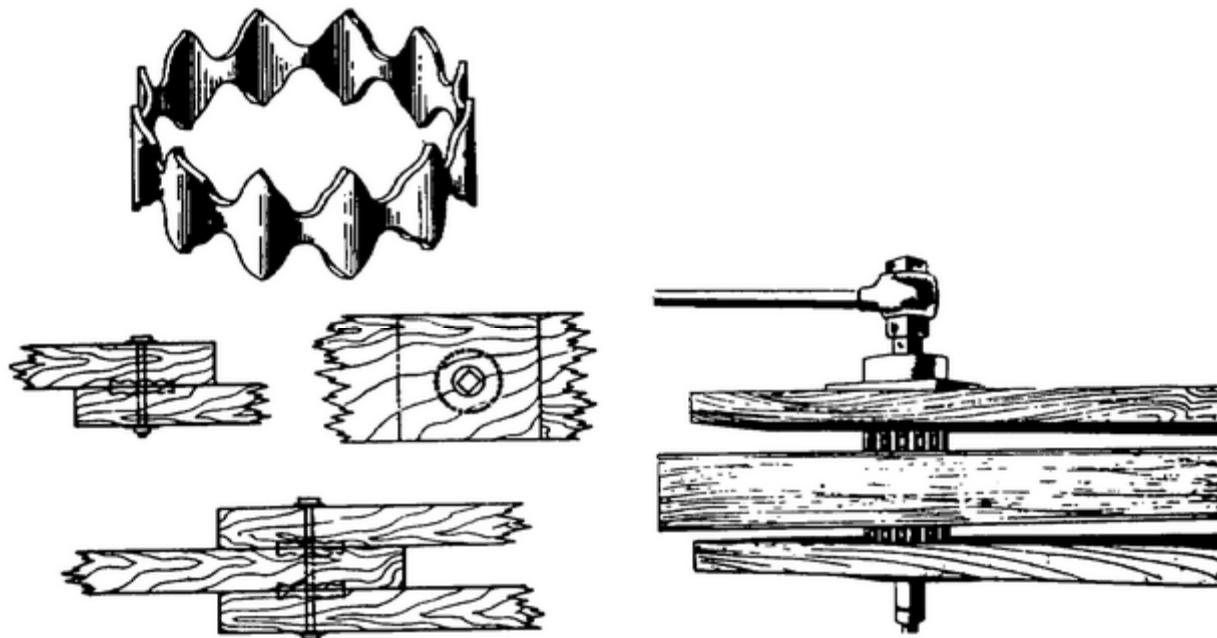


Figure 1-23. Toothed rings and installation.

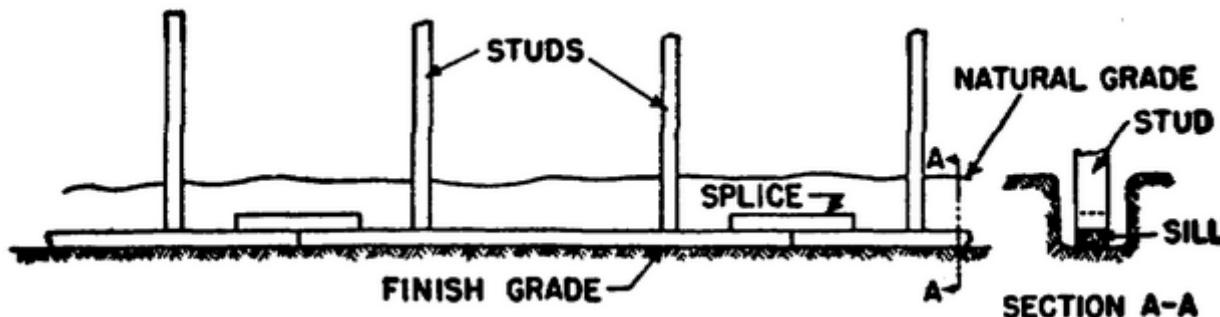


Figure 1-24. Excavating for structure with earth floor.

floor level above the outside and to prevent water seepage. Then wood floors are laid on the ground, the excavated earth should be used to raise the floor level. The pick and shovel should be used to dig small foundations; large foundations may be dug either by hand or with machinery.

1-27. FOUNDATIONS

Foundations vary according to their use and the type of material available. The material may be cut stone, rock, brick, concrete, tile, or wood, depending upon the weight which the foundation is to support. Foundations may be classified as wall or column (pier) foundations.

a. Wall foundations are built solid, the walls of the building being of continuous heavy construction for their total length. Solid walls are used where there are heavy loads to be carried or where the earth has low supporting strength. These walls are made of concrete, rock, brick, or cut stone, with a footing at the bottom (fig. 1-25). Because of the time, labor, and material required to build it, this type of wall will be used in the theater of operations only when other types cannot be used. Steel-rod reinforcements should be used in all concrete walls and columns.

b. Column or pier foundations save time and labor. They may be constructed from masonry or wood. The piers or columns are

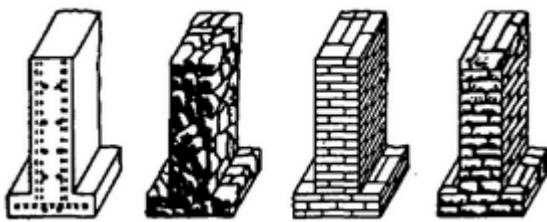


Figure 1-25. Types of foundation walls.

spaced according to the weight to be carried. In most cases the spacing is from 6 to 10 feet. Figure 1-26 shows the different types of piers with different types of footings. Wood piers are generally used since they are installed with the least time and labor. Where wood piers are 3 feet or more above the ground, braces are necessary (fig. 1-7).

1-28. FRAMING

After the building has been laid out and the batter boards set in place, the carpenter proceeds to construct the framework of the building. Framing is the skeleton upon which the covering is to be placed. Just as the bony skeleton is the basic supporting structure of the body, so the framework of a building contains its fundamental strength. The framework consists of the foundation walls, exterior walls, flooring, roofing, beams, trusses, partitions, and ceiling.

a. Substitute, expedient, and improvised framing. The particular form that substitute, expedient, and improvised buildings may take is usually determined by circumstances. Therefore it depends upon the particular nature of such circumstances as the time and place of building, the existence of an emergency, and the form it takes. The ideas included in (1) through (5) below constitute departures from standard plans and the adaptation of natural materials to some circumstances, and may suggest further expedients that would be adjustable to others. Available material and equipment, labor, climatic conditions, and local requirements must all be considered before plans are substituted or amended, or different materials or equipment substituted for standard or recommended items.

(1) Light siding. Chicken wire and water-resistant bituminous-coated paper can be sandwiched to provide adequate temporary cladding in temperate and tropical climates.

(2) Salvaged material. Salvaged sheet metal such as corrugated material or gasoline cans can be utilized as siding in the construction of emergency housing.

(3) Local timber. Poles trimmed from saplings or bamboo can be constructed into reasonably sound framing. Such materials may also be secured with native vines or grasses as a further expedient.

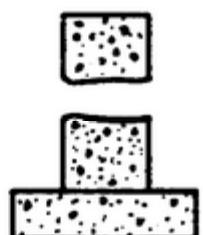
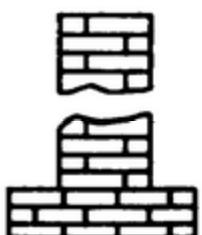
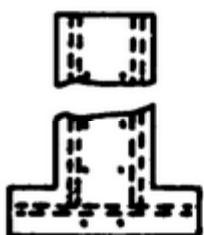
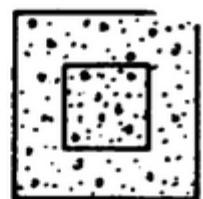
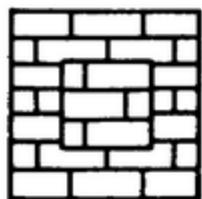
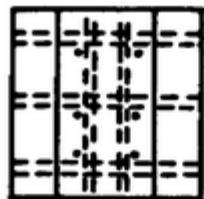
(4) Wood-substitute framing. Adobe, which is soil, straw, and water, "puddled" to proper consistency can be used to form walls, floors, and foundations. This mixture may be used to form sun-dried bricks and be adaptable to construction requirements. Adobe may be used for walls, floors, and/or roofs with adequate support.

(5) Excavations. Proper excavations and simple log cribbing may be covered with sod and carefully drained to provide adequate shelter. This type of construction should be used only under emergency.

b. Light frame construction. Very little of the material used in light construction needs to be framed. Much of the framing that must be done can be accomplished while the staking out and squaring of the budding are being completed. By use of a "shifting" organization, a large force of men can be kept working systematically without loss of time for completion of framing. When an advance crew has the skeleton of a building far enough along so the sides can be boarded, a crew large enough to keep pace with them can be putting on siding and roofing while others are making doors and so forth. Behind the crew nailing on siding, a gang can be roofing. But it must be remembered that those men erecting the frame should be the best men.

1-29. SILLS

a. The work involved in sill construction is very important to the carpenter. The foundation wall is the support upon which all



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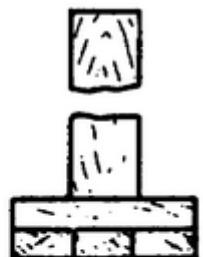
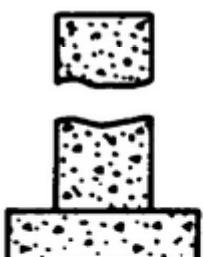
②

③

REINFORCED CONCRETE

BRICK

SQUARE CONCRETE



④

⑤

⑥

ROUND CONCRETE

ROUND TIMBER

SQUARE TIMBER

Figure 1-26. Types of columns or piers.

superstructure rests. The sill is the foundation on which all framing structure rests, and it is the basic point of departure for actual carpentry and joinery activities. The sills are the first part of the frame to be set in place. They rest either directly on the foundation piers or on the ground, and may extend all around the building. They are joined at the corners and spliced when necessary.

(1) Built-up sills. Where built-up sills are used, the joints are staggered (1, fig. 1-27). The corner joints are made as shown in 2, figure 1-27.

(2) Box sills. Box sills are often used with the very common style of platform framing, either with or without the sill plate. In this type of sill (1, 2, fig. 1-28), the part that lies on the foundation wall or ground is called the sill plate. The sill is laid edgewise on the outside edge of the sill plate.

(3) T-Sills. There are two types of T-sill construction; one commonly used in dry, warm climates (3, fig. 1-28), and one commonly used in moderate climates (4, fig. 1-28). Their construction is similar, except that in the case of the moderate-climate T-sill the joists are nailed directly to the studs, as well as to the sills, and headers are used between the floor joists.

b. If piers are used in the foundation, heavier sills are used. These sills are of single heavy timbers or are built up of two or more pieces of timber. When heavy timbers or built-up type sills are used, the joints should occur over the piers. The size of the sill depends upon the load to be carried and upon the spacing of the piers.

1-30. GIRDERS

a. Description. Girders are large beams used to support floor joists and concentrated loads at particular points along their length (fig. 1-7). A girder may be either a single beam or a built-up composite. Girders usually support joists; the girders themselves are supported by piers or bearing walls. When a girder is supported by a foundation wall or pier, it must be remembered that such a girder delivers a large concentrated load to a small section of the pier or, to a lesser extent,

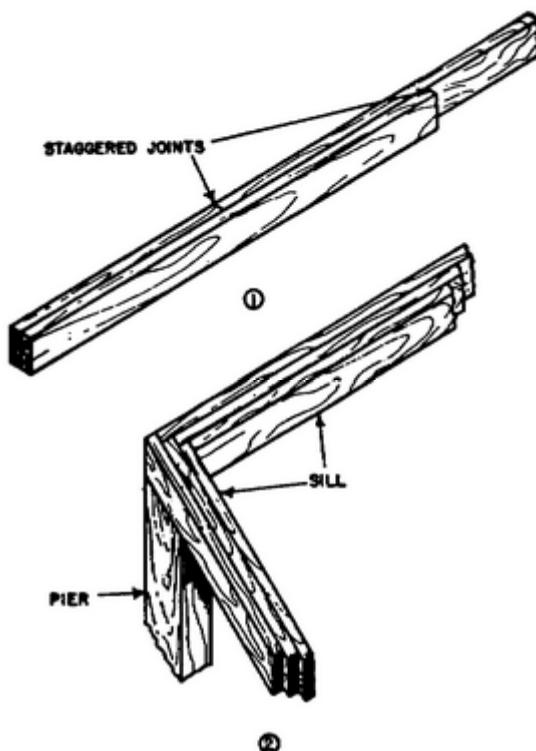


Figure 1-27. Sill fabrication.

to a wall; therefore, care must be taken to see that such a pier or wall is strong enough in its column action to carry the load imposed upon it by the girder. When softwood is used for girders it may be necessary to insert a hardwood bolster between the girder and pier to prevent crushing as illustrated in figure 1-29. Girders are needed to support floor joists wherever the width or length of the structure makes it impossible to use joists over the full span. The full span is considered to be from foundation wall to foundation wall. The size of these girders is determined by the span and the load to be carried. In general, the size of a beam or girder varies directly as the square of the length of the span; thus, if one span is twice as great as another, the girder for the longer span should be four times as strong as the girder for the shorter span. Sizes of girders for various loads and spans, designed for military construction in a theater of operations, are given in table 1-7.

b. Construction. Girders can be built up of wood if select stock is used. Be sure it is

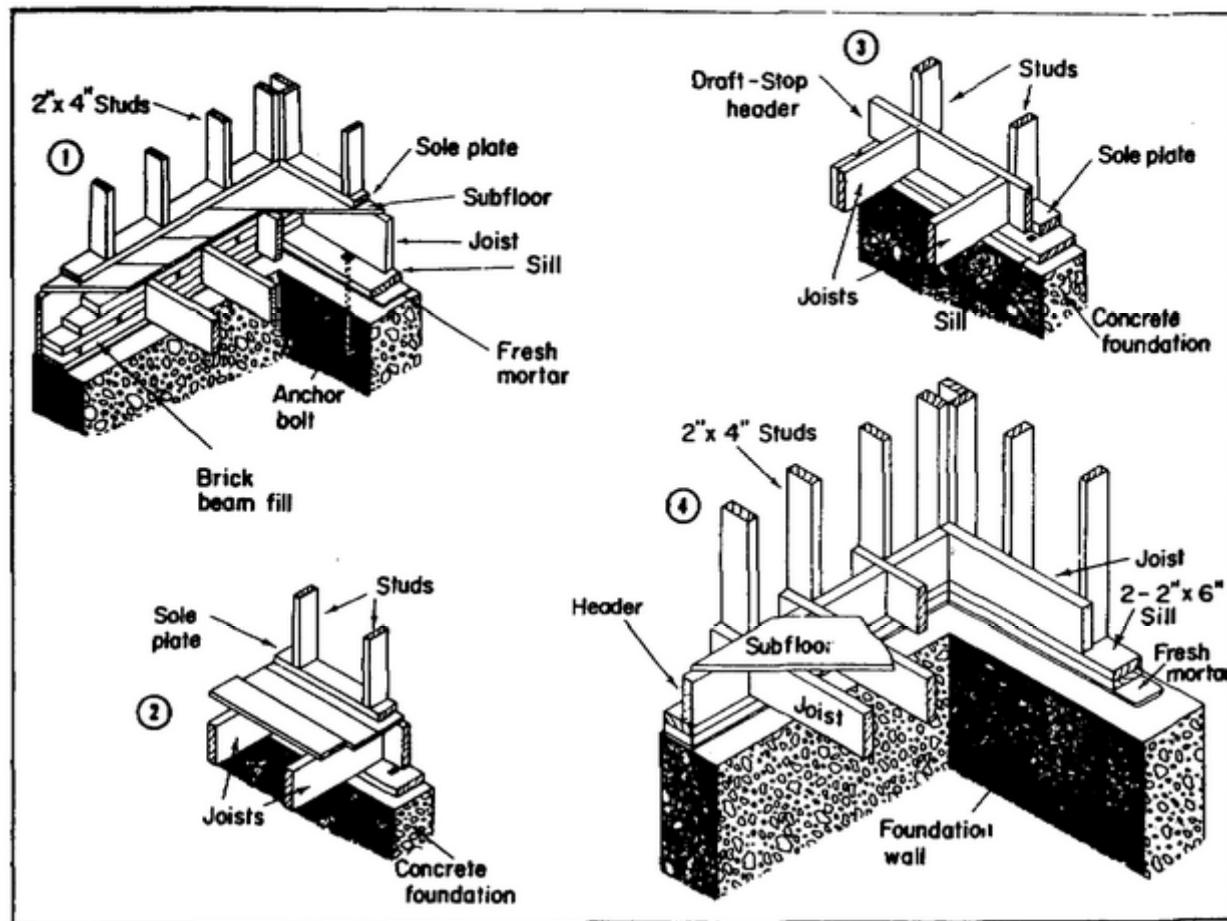


Figure 1-28. Types of sills.

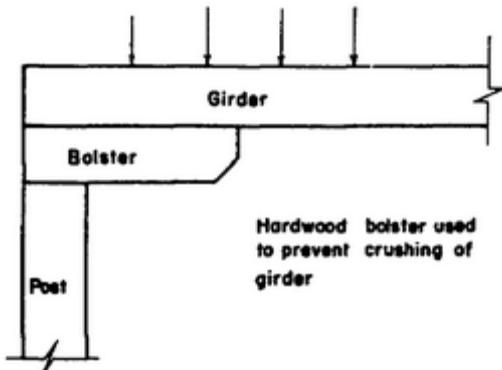


Figure 1-29. Protecting girder with hardwood bolster.

straight and sound. Square off ends of stock, if necessary. If the girder is to be built up of 2 x 8 or 2

x 10 stock, place pieces on the saw horses and nail together. Use the piece of stock that has the least amount of wind or warp for the center piece and nail other pieces on sides of center stock. Square off the ends of the girders after the pieces have been nailed together if necessary. If the stock is not long enough to build up the girder the entire length, the pieces must be built up by staggering the joints as in the case of the built-up sills (fig. 1-27). Girders are often built up by placing two or more joists side by side and nailing them together. For a girder of two joists, 16-penny nails should be used; for a girder of three joists, 20-penny nails should be used; and for girders of four or more joists, 20- or 30-penny nails should be used. The nails must be placed about 1 1/2 inches from the top and bottom edges of the joist, spaced about 24 inches apart, and staggered; they should be driven from both

TABLE 1-7. Sizes of Built-up Wood Girders for Various Loads and Spans (Based on Douglas Fir 4-Square Guideline Framing)

sides of the girder alternately. If the girder-supporting pier is to be built up, it is to be done in the same manner as described for the girder.

1-31. FLOOR JOISTS

Joists are the pieces which make up the body of the floor frame. The flooring or subflooring is nailed to them. They are usually 2 or 3 inches thick and the depth is varied to suit the conditions. Joists as small as 2 x 6 are sometimes used in light buildings, but these are too small for floors with spans more than 10 feet though they are frequently used for ceiling joists.

Joists usually carry a uniform load composed of the weight of the joists themselves, plus superimposed loads of materials and personnel. The latter loads are commonly termed "live loads;" the weight of joists and floors is called "dead load." The joists carry the flooring directly on their upper surface, and first-floor joists are supported at their ends by sills and by girders (fig. 1-7). Joists in second and subsequent floors are supported by bearing partitions, or bearing walls. They are spaced 16 or 24 inches apart, center to center. If additional strength is necessary, it is normally obtained

through the use of heavier joists rather than by closer spacing. However, in some instances, such as under a safe, it may be desirable to place the joists closer together. Two-inch material should not be used for joists more than 12 inches in depth.

1-32. METHOD OF CONNECTING JOISTS TO SILLS AND GIRDERS

a. Connecting to sills. In joining joists to sills, always be sure that the connection is able to hold the load that the joists will carry. 1, figure 1-30 shows the joists resting upon the sill. This method is the most commonly used because it gives the strongest possible joint. The methods shown in 2, 3, figure 1-30 are used where it is not desirable to use joists on top of the sill. The ledger plate should be

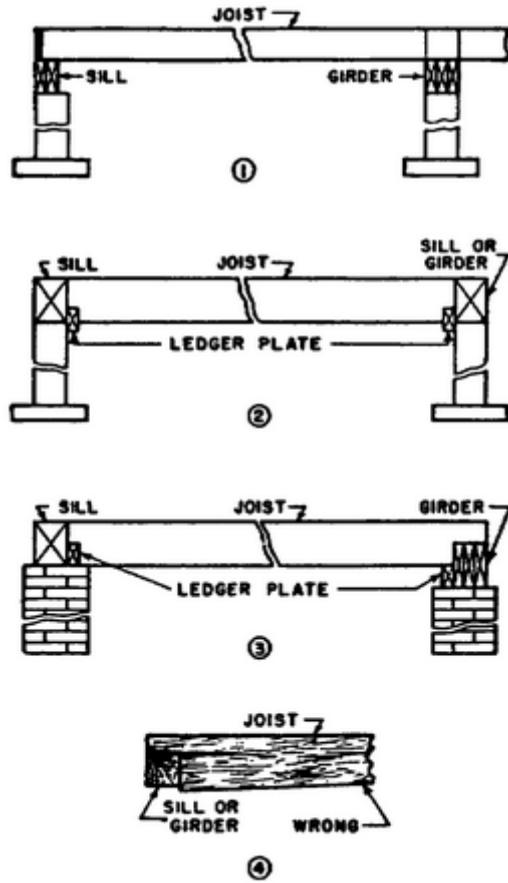


Figure 1-30. Sill and joist connections.

securely nailed and the joist should not be notched over one-third of its depth. 4, figure 1-30 shows the result of notching too deeply. There are several other methods, but those mentioned above are more or less standard. In the theater of operations it is up to the officer in charge of the carpenters to determine the method to be used; he must keep in mind that time, labor, and material are of vital importance.

b. Connecting to girders. The framing of the joists to the girders may be accomplished in several ways, depending upon the position of the girder. The placing of the girders is an important factor. The joists must be level; therefore, if the girder is not the same height as the sill, the joist must be notched as shown in 3, figure 1-30. If the girder and sill are of the same height, the joist still must be connected to the sill and girder to keep the joist level. Joists are connected to girders as shown in figure 1-30. In placing joists, always have the crown up since this helps counteract the weight on the joist. Overhead joists are joined to plates as shown in 1, figure 1-31. The inner end of the joist rests on the plate of a bearing partition. When a joist is to rest on plates or girders, either the joist is cut long enough to extend the full width of the plate or girder, or it is cut so as to meet another joist in the center of the girder and connected with a scab (fig. 1-7). Where two joist ends lie side by side on a plate or girder, they should be nailed together (1, figure 1-31). In 2, figure 1-31 the end of the joist rests on a wall plate.

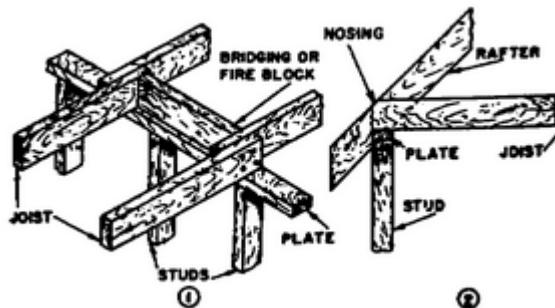


Figure 1-31. Joist connections to plate.

c. **Use of ledger plates.** In connecting joists to girders and sills where piers are used, a narrow piece of 2-inch lumber is nailed to the face of the sill or girder, flush with the bottom edge; this is called a "ledger plate" (fig. 1-32). These pieces should be nailed securely with 20-penny nails about 12 inches apart. Where 2 x 6 or 2 x 8 joists are used, it is better to use 2 x 2's to prevent the joists from splitting at the notch. When joists are 10 inches deep or deeper, 2 x 4's may be used without reducing the strength of the joists. If a notch is used, joist ties may be used to overcome this loss of strength, as shown in figure 1-2. These ties are short 1 x 4 boards nailed across the joist; the ends of the boards are flush with the top and bottom edges of the joists.

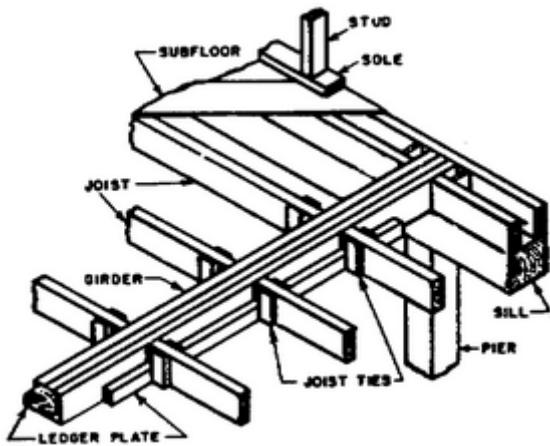


Figure 1-32. Ledger plates (or strips).

1-33. BRIDGING

When joists are used over a long span they have a tendency to sway from side to side. Floor frames are bridged in order to stiffen the floor frame, to prevent unequal deflection of the joists, and to enable an overloaded joist to receive some assistance from the joists on either side of it. Bridging is of two kinds horizontal bridging (1, fig. 1-33) and cross bridging (2, fig. 1-33). Cross bridging is the one most generally used; it is more effective and requires less material than horizontal bridging. Cross bridging looks like a cross and consists of pieces of lumber, usually 1 x 3 or 2 x 3, put in diagonally between the joists.

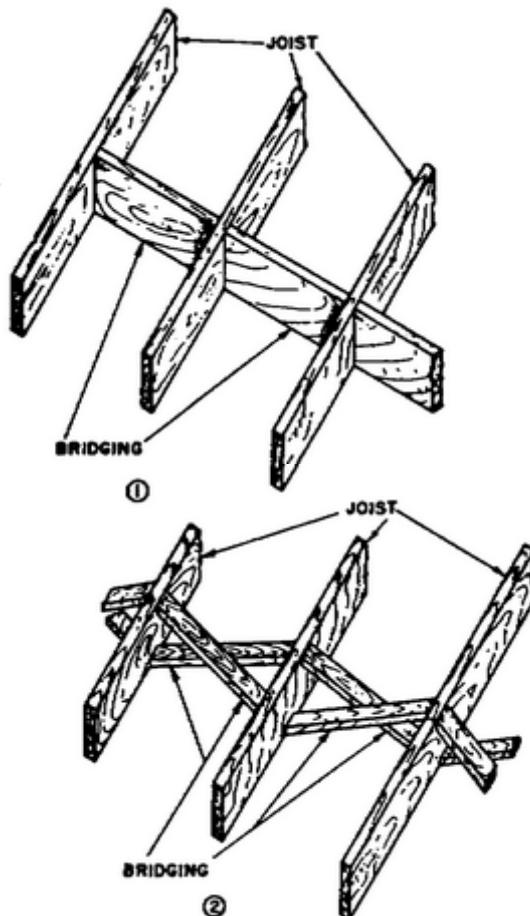


Figure 1-33. Types of bridging.

joists. Each piece is nailed to the top of each joist and forms a cross between the joists. These pieces between joists should be placed as near to each other as possible. Bridging should be nailed with two 8- or 10-penny nails at each end. The tops should be nailed and the bottoms left with nails driven through the bridging only until the subfloor or finish floor is laid. This permits the joists to adjust themselves to their final positions. The bottom ends of bridging may then be nailed, forming a continuous truss across the whole length of the floor and preventing any overloaded joist from sagging below the others. Cutting the bridging by hand is a slow process; on large jobs a power saw should be used if it is available. After the joists have once been placed, a pattern may be made and used to speed up the process of cutting. On joists more than 8 feet long, one

line of bridging should be placed, and on joists more than 16 feet long, two lines.

1-34. SUBFLOOR

Subfloor, if used, is laid diagonally on the joists and nailed with 8- or 10-penny nails, the number of nails depending upon the width of the boards. Boards 8 inches wide or over should have three or more nails per joist. Where the subfloor is more than 1 inch thick, larger nails should be used. By the use of subflooring, floors are made much stronger since weight is distributed over a wider area. Figure 1-7 shows the method of laying a subfloor. It may be laid before or after the walls are framed, preferably before as it can then be used as a floor to work on while framing the walls.

1-35. REINFORCED JOISTS

In certain parts of the floor frame, in order to support a bearing partition or some other heavy, concentrated load, it may be necessary to construct reinforced joists (fig. 1-34 (1)). If spacing is required for heat ducts, solid blocking should be used between the joists (fig. 1-34 (2)(A)).

1-36. HEADERS AND TRIMMERS

A girder may also be necessary in a floor when

an opening is to be left in the floor for some other structure. The timbers on each side of such an opening are called "trimmers," and these must be made heavier than the ordinary joists. A piece called a "header" must be framed in between them to receive the ends of the short joists as shown in figure 1-35. To frame an opening of thin type, first install joists A and C (fig. 1-35), then cut four pieces of timber that are the same size as the joists with the length corresponding to the distance between the joists A and C at the outside wall. Nail two of these pieces between the joists at the desired distance from the ends of the joists; these pieces are shown as headers Nos. 1 and 2. Install short joists X and Y, as shown. The nails should be 16- or 20-penny nails. By omitting headers Nos. 3 and 4 and joists B and D temporarily, the short joists X and Y can be nailed in place through the header and the headers can be nailed through the joists A and C into its end. After the header and short joists have been securely nailed, headers Nos. 3 and 4 are nailed beside Nos. 1 and 2. Then joist B is placed beside joist A and joist D beside joist C, and all are nailed securely.

1-37. FOUNDATION LAYOUT

The objectives of surveying for building construction are to lay out the proposed

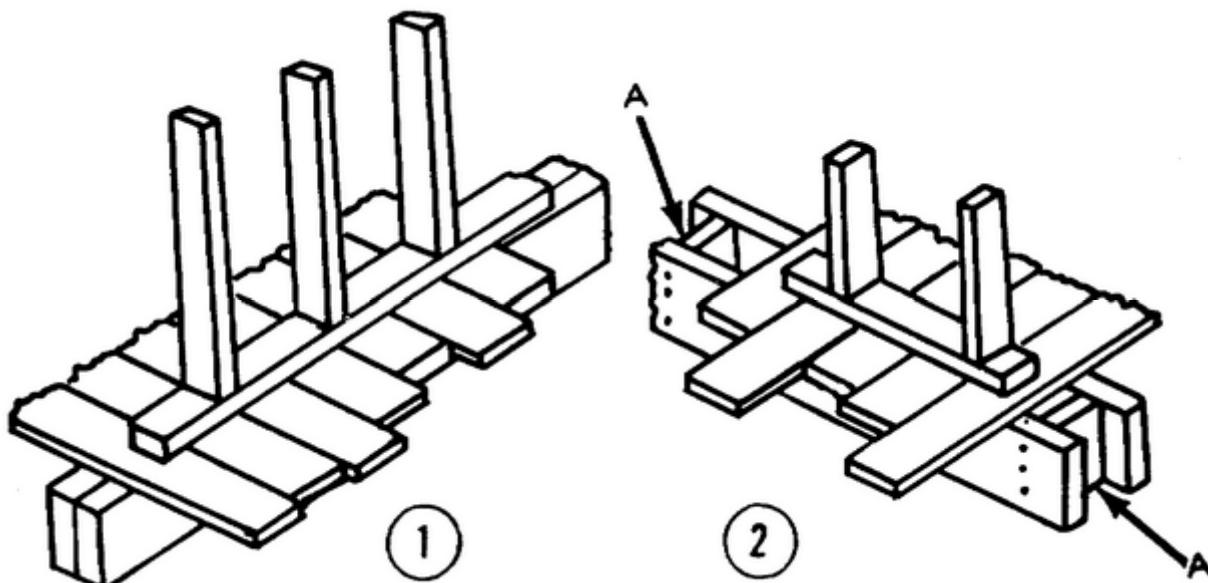


Figure 1-34. Reinforced joists.

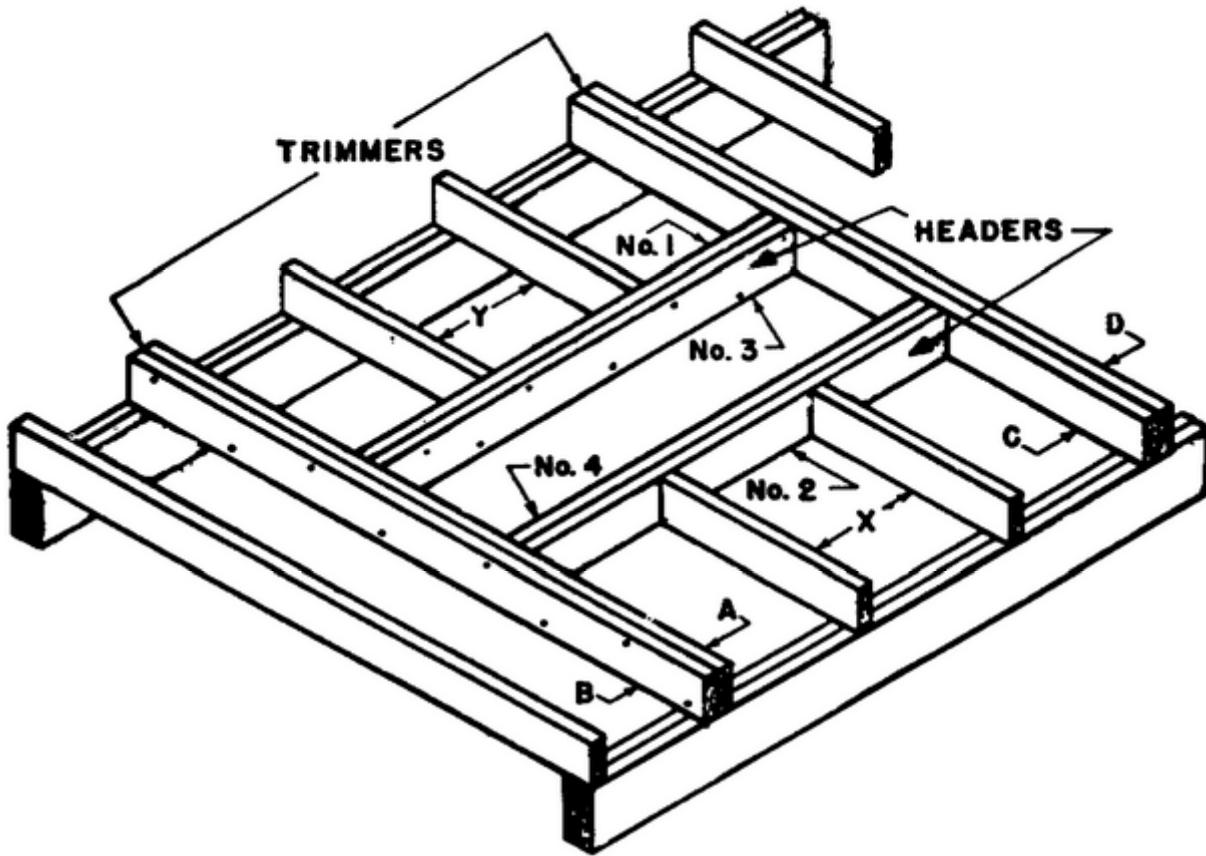


Figure 1-35. Headers and trimmers.

structure according to prepared plans and to mark the controlling points of the structure in the manner that is most useful to the construction force. This marking consists of indicating the corners of the building and other horizontal and vertical positions by means of stakes, batter, boards with string-lines, and cut-and-fill notations.

1-38. LAYING OUT A SIMPLE RECTANGLE WITH AN ENGINEER'S TRANSIT OR LEVELING INSTRUMENT

The procedures for a typical simple budding layout are shown in figure 1-36.

- Establish baseline AB from a reference monument or bench mark, or a fixed line such as a street curb, and then locate point C and D on the baseline by measurement.
- With the transit at point C, backsight on point B, turn a 90° angle, and locate and place corner stakes E and F by measurement and determine their elevation.

c. Move transit to point D, backsight on point A, turn a 90° angle, and locate and place corner stakes G and H by measurement and determine their elevation.

d. Install batter boards and wire to retain the layout during excavation and construction.

e. Check the squareness of the layout by measuring the length of the diagonals, EH and FG and comparing it with the length computed by $c = \sqrt{a^2 + b^2}$ where c is the computed diagonal length and a and b are the lengths of the two sides (see calculation of diagonal, fig. 1-6). The squareness can also be checked by using a 3 - 4 - 5 right triangle or carpenter's square to check the 90° angle at the corners. The procedure of laying out a simple rectangle with a measuring tape is the same as with an engineer's

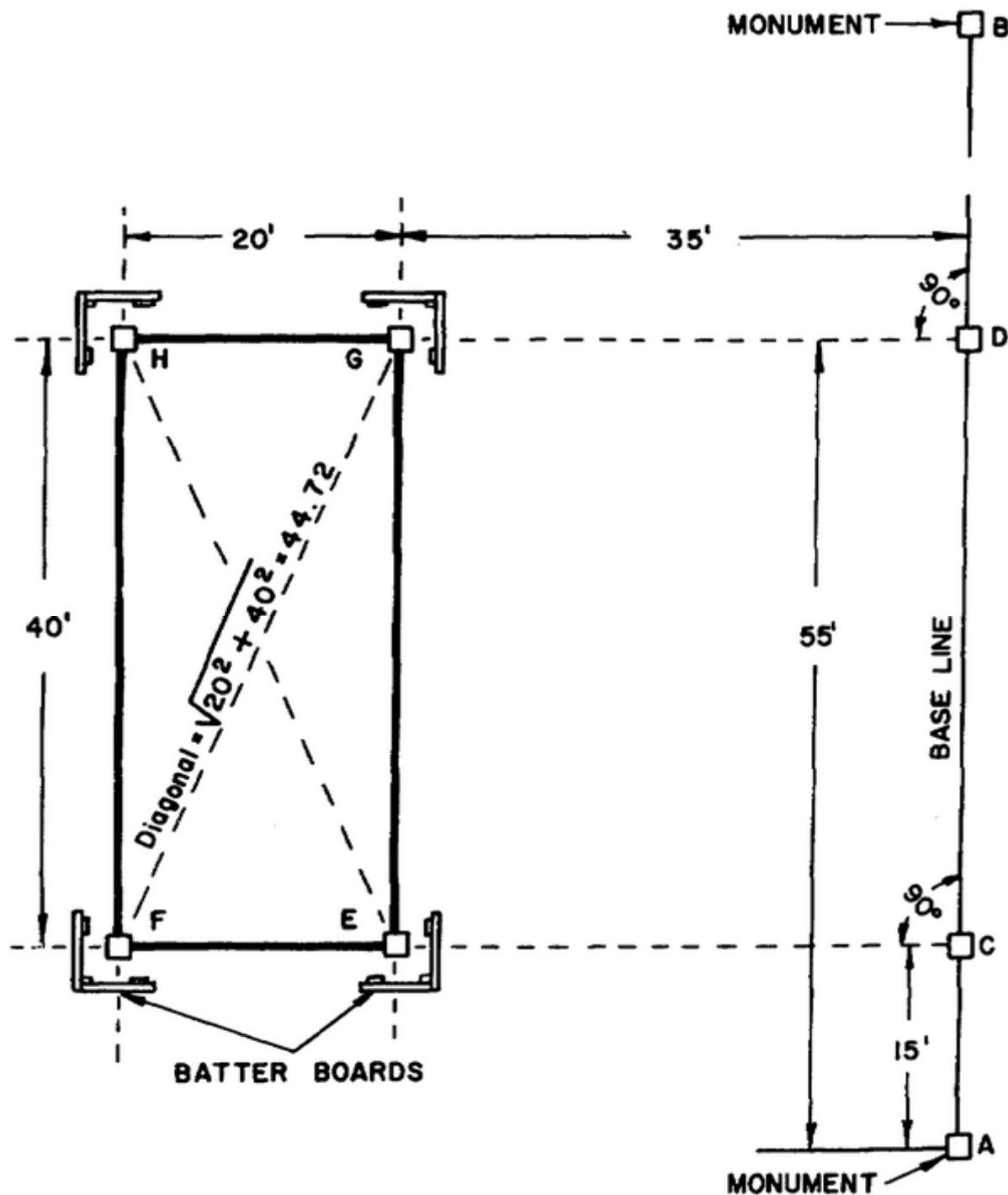


Figure 1-36. Method of laying out a simple rectangular building.

transit except the right angles are established by the use of the measuring tape. A right triangle with sides equal to 3 - 4 - 5 or a multiple thereof is formed and is used to lay off the 90° at the turns.

1-39. LAYING OUT AN IRREGULARLY SHAPED PROJECT

When the outline of the building is not a simple rectangle, the procedure in establishing each point is the same as described above, except that more points have to be located and the checking of the work is more likely to reveal a small error. After having established the baseline, it is usually advisable with an irregularly shaped building to lay out first a large rectangle which will comprise the entire building or a greater part of it. This is shown in figure 1-37 as rectangle HQRS. Having once established this accurately, the remaining portion of the layout will consist of small rectangles, each of which can be laid out and checked separately.

1-40. BATTER BOARDS

a. Staking procedure. At the points where the corners of the building are located,

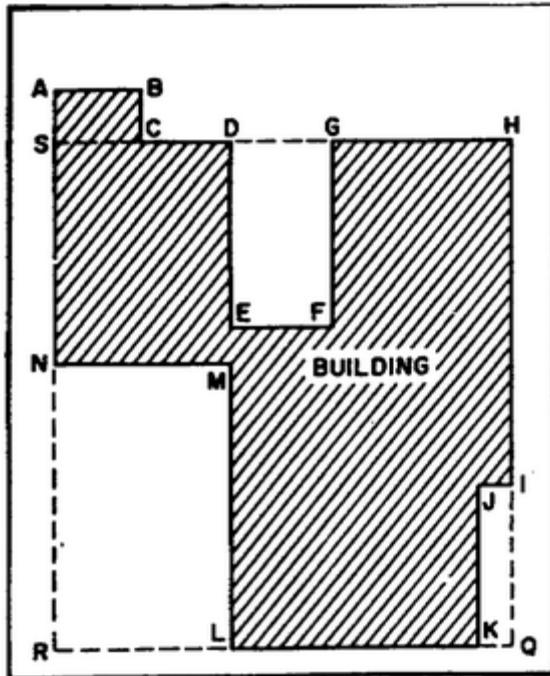


Figure 1-37. Layout of an irregularly shaped project.

stakes are driven to mark the exact spots (fig 1-38). If the area must be excavated for foundation, the excavating will disturb the pegs. Batter boards are therefore set up to preserve definite and accurate building lines to work toward or from. This is accomplished by stretching heavy cord or fine wire from one batter board to the other so as to define the lines of excavations.

b. Locating batter boards. Right-angle batter boards are erected 3 or 4 feet outside each corner stake (fig. 1-38), and straight batter boards are erected 3 or 4 feet outside of line stakes set at points provided for the extension of foundation lines which intercept side lines.

c. Construction of batter boards. Batter board stakes may be 2 x 4, 2 x 6 or 4 x 4. They must be heavy enough to be sturdy when driven and withstand all ordinary working conditions. They are driven far enough apart to straddle the line to be marked. The length of the stakes is determined by the required finished grade line and required height above ground. If the height above ground is more than 3 feet, they should be braced. The 1 x 6 crosspiece is cut long enough to join both stakes and is nailed firmly to them after the grade has been established. The top of the crosspiece then becomes the mark from which the grade will be measured. All batter boards for one structure are set to the same grade of level line. It is best to use a transit to locate the building lines. The building lines are marked on the crosspiece with a nail or saw cut. Separate cuts or nails may be used for the building line, foundation line, hooting line, and excavation line. These grooves and nails permit the removal and replacement of the lines or wires in correct position.

1-41. PROCEDURE FOR ESTABLISHING LINES FROM BATTER BOARDS

Referring to figure 1-39, the following procedure applies to a simple layout and must be amended to apply to different or more complex layout problems.

a. After locating and sinking corner stakes A and B, erect batter boards 1, 2, 3,

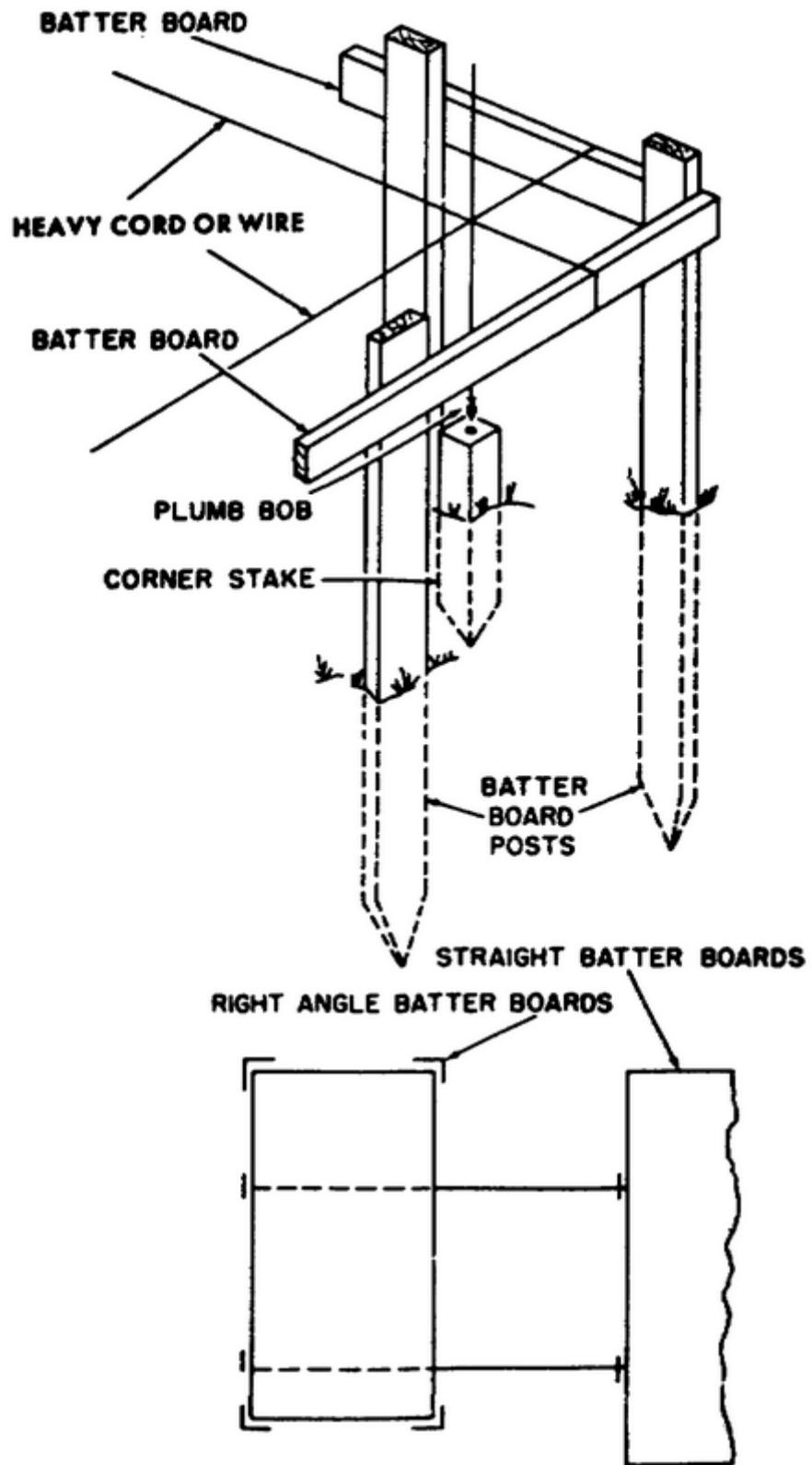


Figure 1-38. Batter boards.

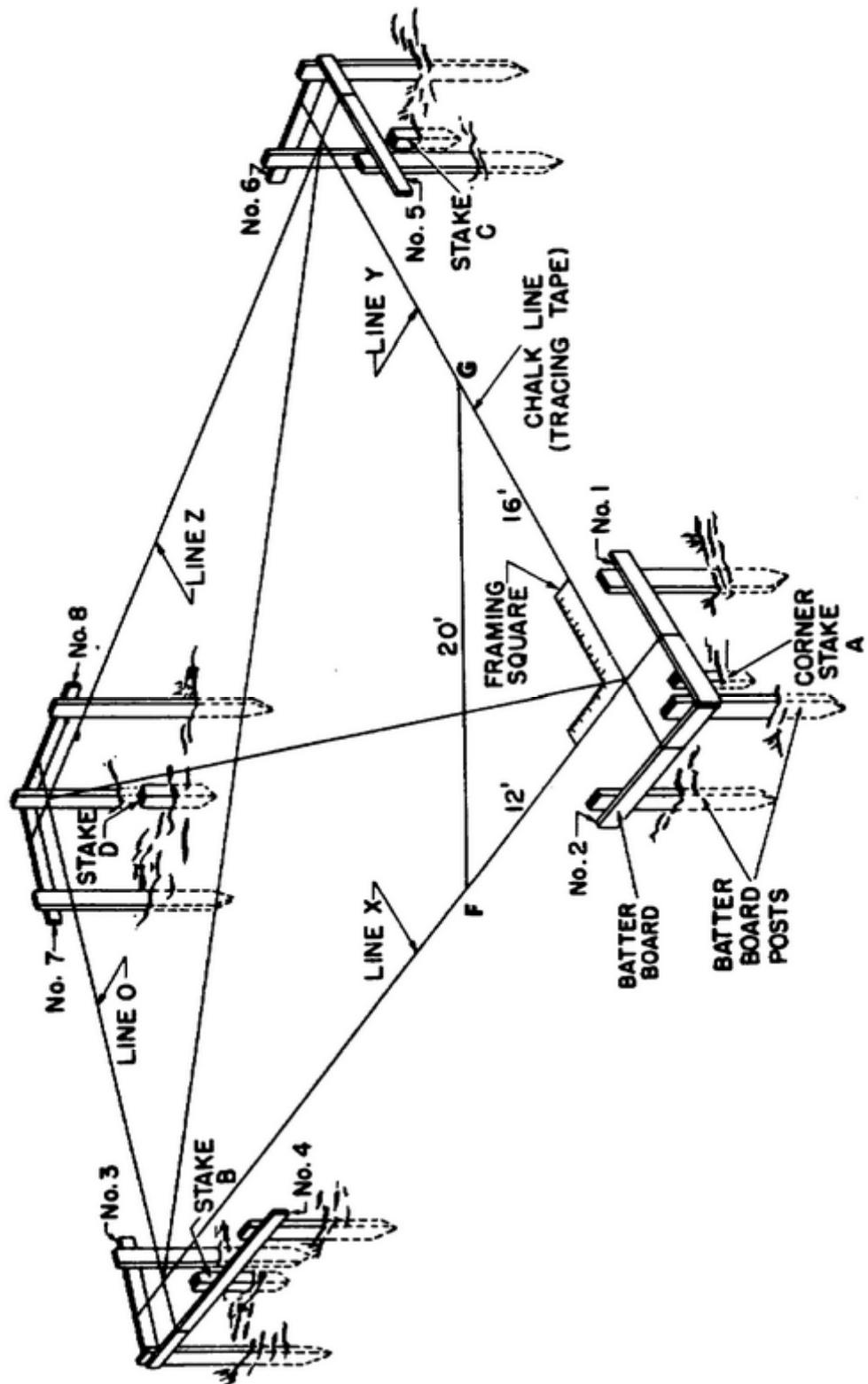


Figure 1-39. Establishing building lines from batter boards.

and 4. Place the wire X from batter board 1 over stakes A and B to batter board 3.

b. After locating and sinking stake C erect batter boards 5 and 6. Place the wire Y from batter board 2 over stakes A and C to batter board 6.

c. After locating and sinking stake D, erect batter boards 7 and 8. Place the wire Z from batter board 5 over stakes C and D to batter board 7.

d. Place line O over stakes D and B from batter boards 8 and 4.

e. Since TO buildings are generally built with the top of the subfloor a specified minimum distance off the ground, it will usually be found convenient to mark the height of subfloor above the ground on the batter board post at the "high" corner (the corner where the existing grade is highest). The top of the batter board will be placed at the mark and will represent the top of the subfloor. The first batter board crosspiece is located by placing the top edge crosspiece in line with the mark on the post and leveling the crosspiece with a carpenters level, then fastening the crosspiece to the posts with nails. The same procedure is used for the second batter board crosspiece. Now the problem is to carry this reference level to the other corners, thereby maintaining a truly horizontal plane. This is best done with a transit but it can be accomplished with a line level. With the wire attached to the established batter board, attach a line level at the center of the wire. Move the free end of the wire up and down on the next post until the line is level. Once it is level mark the post and reverse the line level and repeat the process. In many cases, due to variation in position and inaccuracies of the level, the reversal will give a different point on the post, but the variation should not exceed 1 inch. If the variation is greater, repeat the procedure. The point of elevation will be a point

midway between the two marks thus found. Vertical distance can then be measured up or down from the batter board lines.

1-42. SQUARING BUILDING LINES

There are two generally accepted methods for squaring building lines commonly used by the carpenter: the diagonal method and the 3 - 4 - 5 triangle method.

a. **The diagonal method.** If all the corners are square, the diagonals will be of equal length. These diagonals are seldom equal on the first trial; therefore, we must adjust the sides so that the building will be square. Referring to figure 1-39, let us assume that when the diagonals were measured BC was shorter than AD. It has already been established that all sides are the correct length and also that side AB is always the base. Therefore, all of the adjustments are made by moving the wires on batter boards 6 and 8 either to the left or the right. In this case, the wire BD should be moved to the right a sufficient distance on batter board 8, and AC a corresponding distance on batter board 6. The diagonals are then measured. If they are not yet the same length, the process is repeated until the diagonals are equal. When the outline is correct, saw cuts are made in the outside edges of the batter board to mark and hold the correct location of the wires.

b. **3 - 4 - 5 method.** Referring to figure 1-39, the distance AF is measured. AF is 3 feet or a multiple thereof such as 6, 9, or 12. Measure off AG to a distance of 4 feet (8 feet if 6 feet was used for AF, 12 feet if 9 feet was used for AF, or 16 feet if 12 feet was used for AF). Adjust the wires until FG equals 5 feet if the other two measurements used were 3 feet and 4 feet (10 feet if 6 feet and 8 feet were used, 15 feet if 9 feet and 12 feet were used, and 20 feet if 12 feet and 16 feet were used).

SELF TEST

Note: The following exercises comprise a self test. The figures following each question refer to a paragraph containing information related to the question. Write your answer in the space provided below each question. When you have finished answering all the questions for this lesson, compare your answers with those given for this lesson in the back of this booklet. Review the lesson as necessary. Do not send in your solutions to these review exercises.

1. Name the classifications of buildings as authorized by Army regulations and give the expected economic life of each. (Para 1-1)

2. How does the architect who designs a structure convey the information he wishes to the builder? (Para 1-2b)

3. On construction drawings, lines may be light or heavy, solid or broken in several variations, each having a different meaning. What type of line is used to divide objects into equal or symmetrical parts? (Para 1-3c)

4. Although scaling of prints should be avoided as much as possible, when it is essential what scale should be used on drawings of machine work? (Para 1-4a(1))

5. Architectural drawings generally consist of several different views of the structure. What view shows the type, size, and location of plumbing and electrical wiring? (Para 1-5b(8))

6. What type joint is most commonly used for rafter junctions of roof peaks? (Para 1-8e)

7. What is the difference, from the standpoint of use, between a joint and a splice? (Para 1-8, 1-9)

8. There are many types of wood that are suitable for use as building material. What type wood is mostly used by the Army in TO construction? (Para 1-10a)

9. There are several types of decay which render lumber unserviceable for normal TO construction. Which type is the most common and the most dangerous? (Para 1-13a)

10. What classification and grade of lumber is most generally used for the construction of boxes and crates? (Para 1-16b(4))

11. What is meant by the term **board foot**? (Para 1-18a)

12. Three of the most common types of wood fasteners used in the TO are nails, screws, and bolts. Of these three, which is considered the most economical, and which provides the greatest holding power, sizes being comparable? (Para 1-20a)

13. What devices are used between two timber faces to increase the joint strength in timber structures? (Para 1-25b(1))

14. Building foundations are either of the wall or column (pier) type. Which is the most commonly used in TO construction and why? (Para 1-27)

15. In the construction of a frame building, what is the function of the sill? (Para 1-29a)

16. If the width of a structure is too great to use floor joists over the full span, what structural feature can be added to reduce the length of the joists? (Para 1-30a)

17. When cross bridging is used to prevent side sway in joists, why is the bottom not nailed to the joists at the same time as the top? (Para 1-33)

18. After the baseline for a building layout has been established, what is usually the first step in laying out an irregularly shaped building? (Para 1-39)

19. Batter boards are constructed outside the corner stakes of structures. If they are over a certain height they must be braced. What is this height in feet? (Para 1-40c)

20. It is best to check the level of a building with a transit. If a transit is not available, what is the next best means of checking a layout of a building to see if it is approximately level? (Para 1-41e)

LESSON 2

SUPERSTRUCTURES - FRAMING

CREDIT HOURS.....	2
TEXT ASSIGNMENT.....	Attached memorandum. Review lesson 1.
MATERIALS REQUIRED.....	None.

LESSON OBJECTIVES

Upon completion of this lesson you should be able to accomplish the following in the indicated topic areas:

- 1. Nomenclature and function.** Name all the members of the superstructure of a Theater of Operations type framed building, and state its function.
- 2. Walls and partitions.** Supervise the construction of walls and partitions to include

plumbing and bracing, doors, windows, and other details.

- 3. Roofs.** Determine the correct size and length of lumber to use for the different members of a roof truss, and the proper method of construction.
- 4. Light TO type framing.** Plan and supervise construction, when appropriate using the light theater-of-operations type framing.

ATTACHED MEMORANDUM

2-1. WALLS AND PARTITIONS

Walls and partitions are structural elements composed of vertical members called studs, and are usually closely spaced. They are arranged in a row with their lower ends bearing on a long horizontal member, called a bottom plate or sole plate, and with their tops capped with another plate, called a top plate. Double top plates are usually used, especially in bearing walls and bearing partitions. The bearing strength of stud walls is determined by the strength of the studs.

a. Corner posts. The studs used at the corners of fame structures are usually built up from two or more ordinary studs or other dimension stock to provide strength and additional nailing surfaces. After the sill and first-floor joists are in place, the

first floor is roughly covered to give a surface upon which to work. The corner posts are set up plumbed, and temporarily braced. The corner posts may be made up of boards in several different ways (fig. 2-1).

(1) A corner post may consist of a 4x6 with a 2x4 nailed on the broad side, flush with one edge (1, fig. 2-1). This type of corner is primarily for a 4-inch wall. Where walls are thicker, heavier timber is used.

(2) A 4x4 may be used with 2x4's nailed to two of the adjoining sides (2, fig. 2-1).

(3) Two 2x4's may be nailed together with blocks between and another 2x4 nailed flush with one edge (3, fig. 2-1).

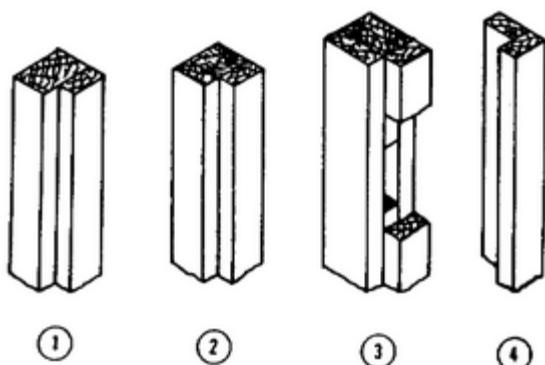


Figure 2-1. Corner post construction.

(4) A 2x4 may be nailed to the edge of another 2x4, the edge of one flush with the side of the other (4, fig. 2-1). This type is used extensively in TO construction where no inside finish is required.

b. T-posts. In conventional framing, whenever a partition meets an outside wall or another partition, a stud wide enough to extend beyond the partition of both sides is used. This affords a solid nailing base for the inside wall finish. This type of stud is called a "T-post" and is made in several different ways (fig. 2-2).

(1) A 2x4 may be nailed and centered on the face side of a 4x6 (1, fig. 2-2).

(2) A 2x4 may be nailed and centered on two 4x4's nailed together (2, fig. 2-2).

(3) Two 2x4's may be nailed together with 2x4 blocks between them and a 2x4 centered on the wide side (3, fig. 2-2).

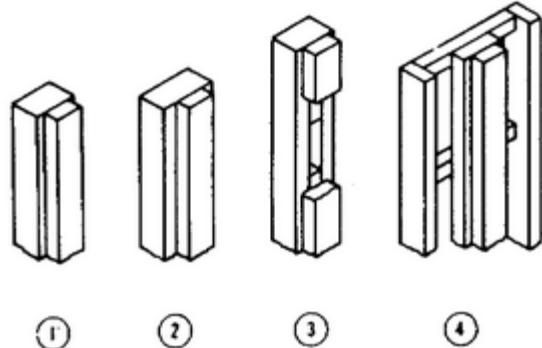


Figure 2-2. T-post construction.

(4) A 2x4 may be nailed and centered on the face side of a 2x6, with a horizontal bridging nailed behind them to provide support and stiffness (4, fig. 2-2).

(5) Where a partition is finished on one side only as in most TO construction, the partition post used consists of a simple stud, set in the outside wall, in line with the side of a partition wall, and furnished as stud A in 1, figure 2-3. The exact position of the partition walls must be determined before the posts are placed. Where the walls are more than 4 inches thick, wider timber is used.

c. Double T-posts. In special cases, for example where partition walls cross, a double T-post is used. This is made by using T-post construction (1, 2, or 3, fig. 2-2), modified by nailing another 2x4 to the opposite wide side, as shown in 2, 3, and 4, figure 2-3.

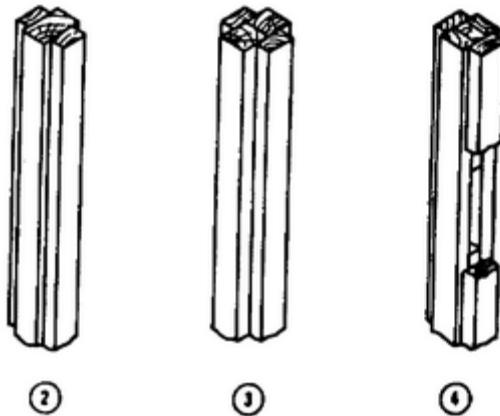
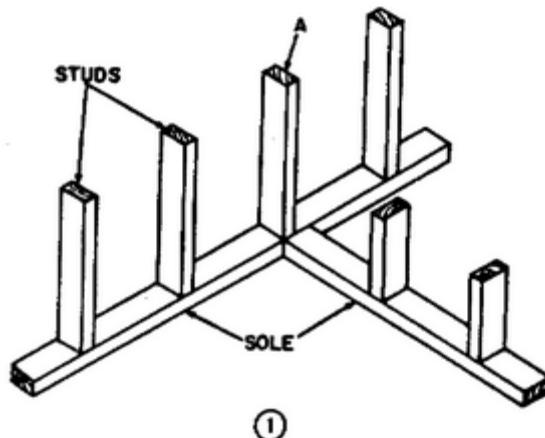


Figure 2-3. Partition posts.

d. Studs.

(1) After the sills, posts, plates, and braces are in place, the studs are placed and nailed with two 16- or 20-penny nails through the top plate. Before the studs are set in place, the window and door openings are laid out. Then the remaining or intermediate studs are laid out on the sills or soles by measuring from one corner the distances the studs are to be set apart. Studs are set from 1 to 12 feet apart, depending upon the type of building, whether girts are used, and the type of outside and inside finish. Where vertical or large-panel siding is used, studs may be set wider apart and horizontal girts provided between them to afford nailing surfaces. For residential work in the United States studs are commonly spaced on 16-inch centers; in TO construction, if girts are used, studs are usually spaced 4 feet apart.

(2) When it is desirable to double the post of the door opening, first place the outside studs into position and nail them securely. Then cut short studs, or filler studs, the size of the opening and nail these to the inside face of the outside studs as shown in figure 2-4. In making a window opening, a bottom header must be framed. This header is either single or double. When it is doubled, the bottom piece is nailed to the opening studs at the proper height, and the top piece of the bottom header is nailed into place flush with the bottom section. The door header is framed as shown in figure 2-4. The filler stud rests on the sole at the bottom.

e. Top plate and sole plate.

(1) **Top plate.** The top plate serves as a connecting link between the wall and the

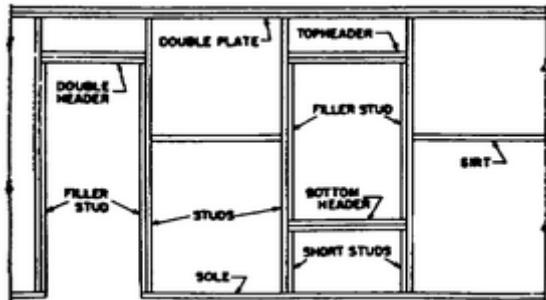


Figure 2-4. Door and window framing.

roof, just as the sole plates are connecting links between the floors and the walls. The plate is made up of one or two pieces of timber of the same size as the studs. In cases where the studs at the end of the building extend to the rafters, no plate is used at the end of the budding. When it is used on top of partition walls it is sometimes called the cap. Where the plate is doubled, the first plate or bottom section is nailed with 16 or 20-penny nails to the top of the corner post and to the studs; the connection at the corner is made as shown in 1, figure 2-5. After the single plate is nailed securely and the corner braces are nailed into place, the top part of the plate is then nailed to the bottom section by means of 16- or 20-penny nails, either placed over each stud or spaced with two nails every 2 feet. The edges of the top section should be flush with the bottom section and the corner joints lapped as shown in 2, figure 2-5. Where only a single plate is used the end studs of two walls forming a corner are spiked together as shown in 4, figure 2-1.

(2) **Sole plate.** All partition walls and outside walls are finished at the bottom with a piece of timber corresponding to the thickness of the wall. This timber, which is usually a 2 x 4, is laid horizontally on the subfloor or, occasionally, on the joists. It carries the bottom end of the studs (1, fig. 2-3). This timber is called the "sole" or "sole plate". The sole should be nailed with two 16- or 20-penny nails at each jolt that R crosses. If it is laid

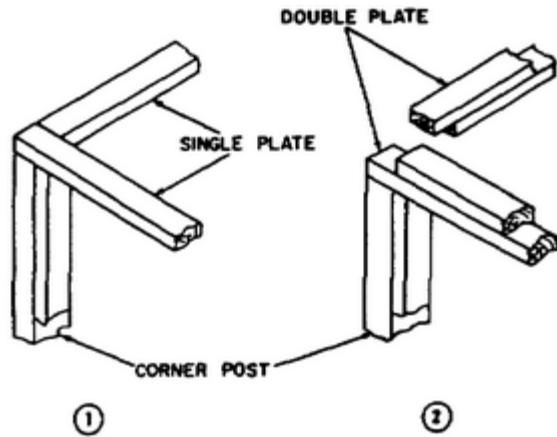


Figure 2-5. Plate construction.

lengthwise on top of a girder or joist, it should be nailed with two nails every 2 feet.

f. Bridging. Frame walls are bridged, in most cases, to make them more sturdy. There are two methods of bridging:

(1) Diagonal bridging. Diagonal bridging is nailed between the studs at an angle (1, fig. 2-6). It is more effective than the horizontal type since it forms a continuous truss and tends to keep the walls from sagging. Whenever possible, both inside and outside walls should be bridged alike.

(2) Horizontal bridging. Horizontal bridging is nailed between the studs horizontally and halfway between the sole and the plate (2, fig. 2-6). This bridging is cut to lengths which correspond to the distance between the studs at the bottom. Such

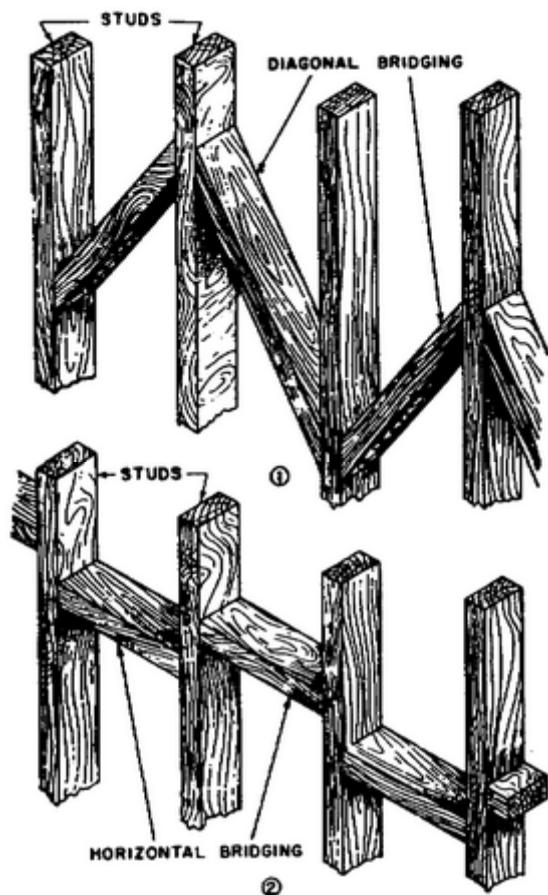


Figure 2-6. Types of wall bridging.

bridging not only stiffens the wall but also helps straighten crooked studs.

g. Partitions. Partition walls are any walls that divide the inside space of a building. These walls in most cases are framed as part of the building. In cases where floors are to be installed after the outside of the building is completed, the partition walls are left unframed. There are two types of partition walls: the bearing and the nonbearing types. The bearing type supports ceiling joists. The nonbearing type supports only itself. This type may be put in at any time after the other framework is installed. On nonbearing partitions only one cap or plate need be used. A sole plate should be used in every case, as it helps to distribute the load over a larger area and provides a suitable nailing base. Partition walls are framed in the same manner as outside walls, and door openings are framed the same as outside openings. If there is to be an inside finish, corner posts or T-posts are used where one partition wall joins another as in the outside walls. These posts provide nailing surfaces for the inside wall finish. The top of the studs has a plate or cap when the partition does not extend to the roof; when the partition does extend to the roof, the studs are joined to the rafters.

2-2. PLUMBING VERTICAL MEMBERS AND STRAIGHTENING WALLS

After the corner posts, T-posts, and intermediate wall studs have been nailed to the plates and the girts, the walls must be plumbed and straightened so that the permanent braces and rafters may be installed. This is done by using a level or a plumb bob and a chalk line.

a. Plumbing posts.

(1) To plumb a corner with a plumb bob, first attach to the bob a string long enough to extend to or below the bottom of the post. Lay a rule on top of the post so that 2 inches of the rule extends over the post or the side to be plumbed. Then hang the bob line over the rule so that the line is 2 inches from the post and extends to the bottom of it, as shown in figure 2-7. With another rule,

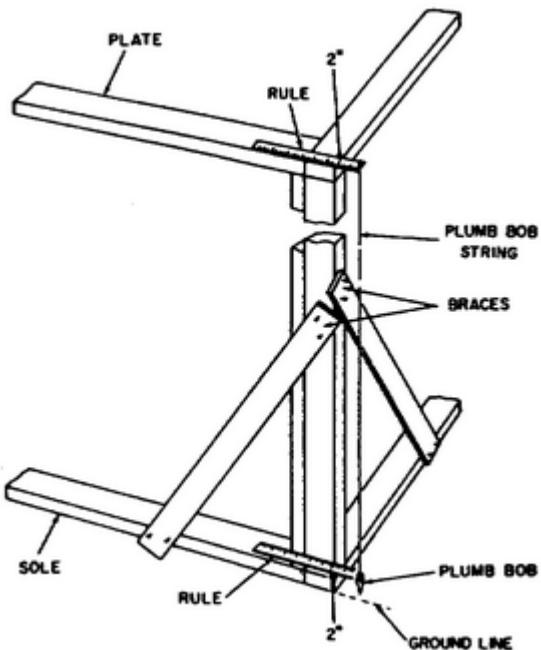


Figure 2-7. Plumbing posts with a plumb bob.

measure the distance from the post to the center of the line at the bottom of the post; if it does not measure 2 inches, the post is not plumb. Move the post inward or outward until the distance from the post to the center of the line is exactly 2 inches. Then nail the temporary brace in place repeat this procedure for the other outside face of the post. The post is then plumb. This process is carried out for the remaining corner posts of the building. If a plumb bob or level is not available, a rock, a half brick, or some small piece of metal may be used instead.

(2) To plumb a corner with a carpenter's level, place the level against each outer face of the post and adjust the post until the level bubble comes to rest exactly between the two scratch marks on the level glass.

b. Straightening walls (fig. 2-8). Plumb one corner post with the level or plumb bob and nail temporary braces to hold the post in place (**a** above). Repeat this procedure for all corner posts. Fasten a chalk line to the outside of one post at the top and stretch the line to the post at the opposite end of the

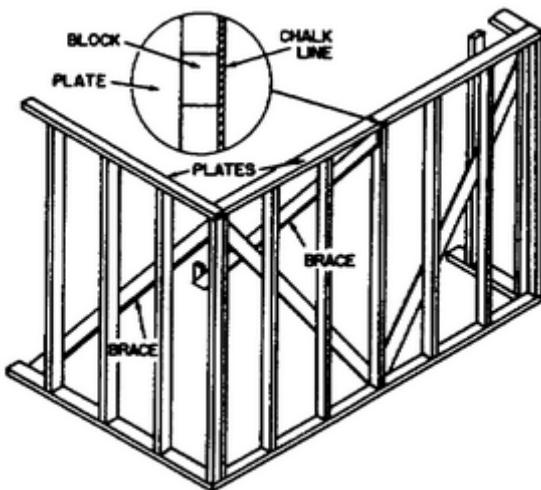


Figure 2-8. Straightening walls.

building, fastening the line to this post in the same manner as for the first post. Place a small 3-4-inch block under each **end** of the line as shown in figure 2-8 to give clearance. Use enough temporary braces to hold the wall straight. When the wall is far enough away from the line to permit a 3/4-inch block to barely slide between the line and the plate, the brace is then nailed. This procedure is carried out for the entire perimeter of the building. Inside partition walls should be straightened in the same manner.

2-3. BRACES

Bracing is used to stiffen framed construction and make it rigid. The purpose of bracing may be to resist winds, storm, twist, or strain stemming from any cause. Good wall bracing keeps corners square and plumb and prevents warping, sagging, and shifts resulting from lateral forces that would otherwise tend to distort the frame and cause badly fitting doors and cracks in the wallboard. There are four commonly used methods of bracing the walls of frame structures:

a. Let-in bracing (1, fig. 2-9). Let-in bracing is set into the edges of studs to be flush with the surface. The studs are always cut to let in the braces; the braces are never cut. Usually 1 x 4's or 1 x 6's are used, set diagonally from top plates to sole plates.

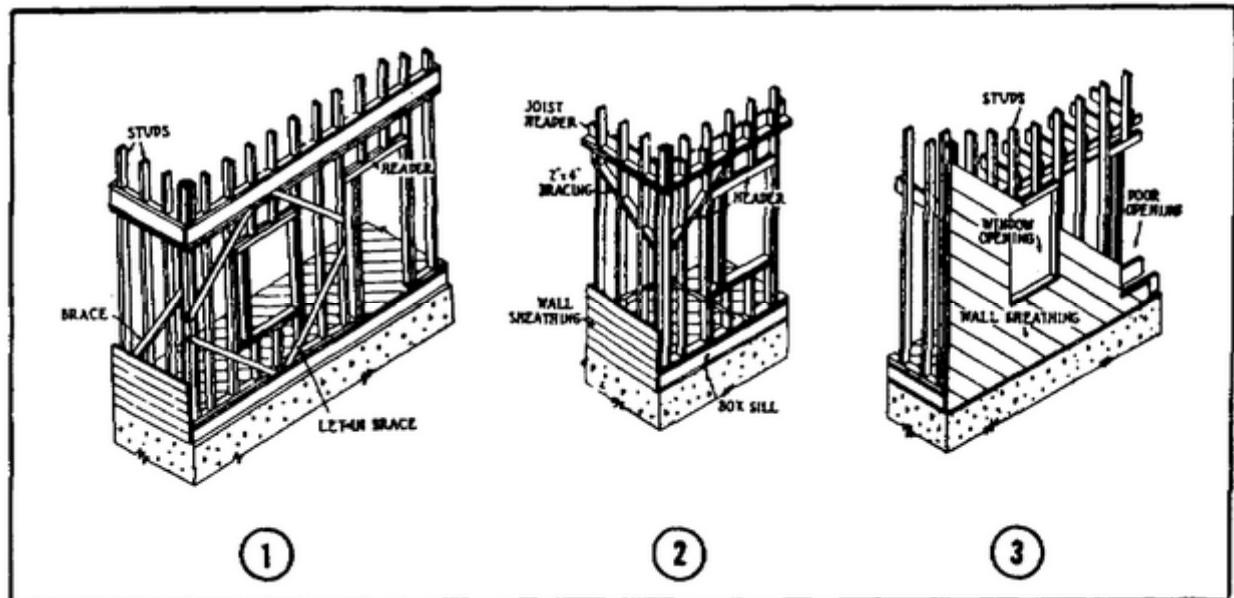


Figure 2-9. Common types of bracing.

b. **Cut-in bracing (2, fig. 2-9).** It usually consists of 2 x 4's cut at an angle to permit toenailing, inserted in diagonal progression between studs and running up and down from corner posts to sills or plates.

c. **Diagonal sheathing (3, fig. 2-9).** The type of bracing with the highest strength is 1-inch nominal thickness sheathing applied diagonally. Each board acts as a brace of the wall. Similarly, if plywood sheathing 5/8-inch thick or more and in 4-by 8-foot panels is used, other methods of permanent bracing may be omitted.

d. **Internal diagonal bracing (fig. 2-8).** Internal diagonal braces are placed wherever the sills, girts, or plates form an angle with corner or T-posts. Diagonal braces consist of material extending from the sill or sole plate to form angles of approximately 60° at the sill or sole. This type of bracing is used only in TO type structures that do not have an interior finish.

2-4. ROOFS

The primary object of a roof in any climate is to keep out the rain and the cold. With the roof covering normally used by the Army, the roof must be sloped to shed water. Where there are heavy snows for long periods of time, roofs must be constructed more rigidly and/or pitched more steeply. They must also be strong enough to withstand high

winds. The most commonly used types of roof construction include:

a. **Gable roof (1, fig. 2-10).** The gable roof is the most commonly used of the various types of roofs. It has two roof slopes meeting at the center, or ridge, to form a gable. This form of roof is the one most commonly used by the Army, since it is simple in design and economical to construct and may be used on any type of structure.

b. **Lean-to or shed roof (2, fig. 2-10).** This roof is used where large buildings are framed under one roof, where hasty or temporary construction is needed, and when sheds or additions to buildings are erected. The pitch of the roof is in one direction only. The roof is held up by the walls or posts on four sides; one wall or the posts on one side are at a higher level than those on the opposite side.

c. **Hip roof (3, fig. 2-10).** The hip roof consists of four sides or slopes running toward the center of the building. Rafters at the corners extend diagonally to meet at the center, or at the end of a ridge. Into these rafters, other rafters are framed.

d. **Gable and valley roof (4, fig. 2-10).** This roof is a combination of two gable roofs intersecting each other. The valley occurs where the two roofs meet, each roof slanting

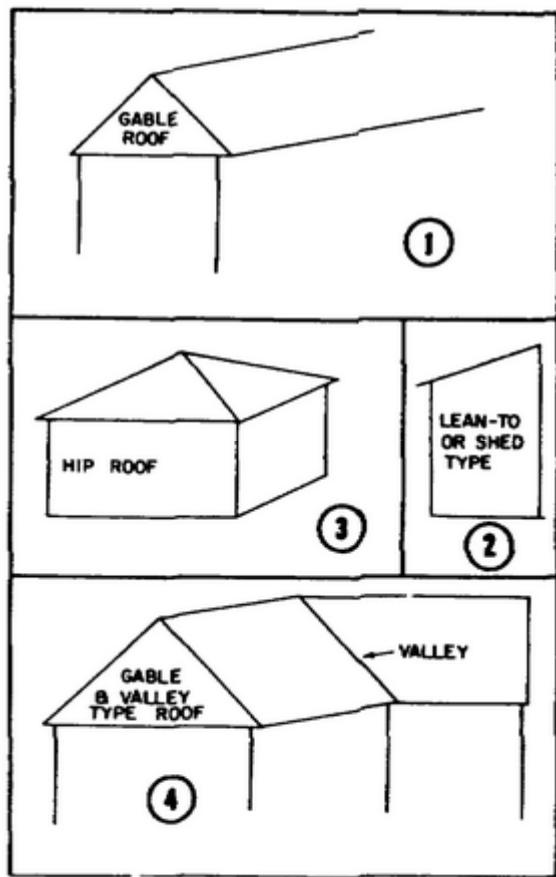


Figure 2-10. Types of roofs.

in a different direction. This type of roof is seldom used in TO construction, since it is complicated and requires much time and labor to construct.

e. **Slope or cut.** The slope of a roof is the angle which the roof surface makes with a horizontal plane. The surface may vary from absolutely flat to a steep slope. The usual way to express roof slope is by means of numbers; for example, 8 and 12, 8 being the rise and 12 the unit of run. Occasionally roof slope is given on plans with some other run than 12, the unit of run. For example, suppose a plan gives the rise as 2 inches per 5 inches of run. In this case the slope can be converted to the standard unit of run by simple proportion:

$$2/5 = x/12 \text{ or } 5x = 24 \text{ or } x = 4 \frac{4}{5}$$

f. **Terms used in connection with roofs.**

(1) **Span.** The span (1, fig. 2-11) of any roof is the shortest distance between the two opposite rafter seats. Stated in another way, it is the measurement between the outside edges of the outside-wall plates, measured at right angles to the direction of the ridge of the building.

(2) **Total rise.** The total rise (1, fig. 2-11, fig. 2-13) is the vertical distance measured from the intersection of the upper edge of the rafter with the building limit line, to the top of the ridge. It is the product of the rise in inches times the total run in feet.

(3) **Total run.** The term total run (1, fig. 2-11) always refers to the level distance over which any rafter (para 5a) passes. For the ordinary gable-roof rafter, this would be one half the span distance.

(4) **Unit of run.** The unit of measurement, 1 foot or 12 inches, is the same for the

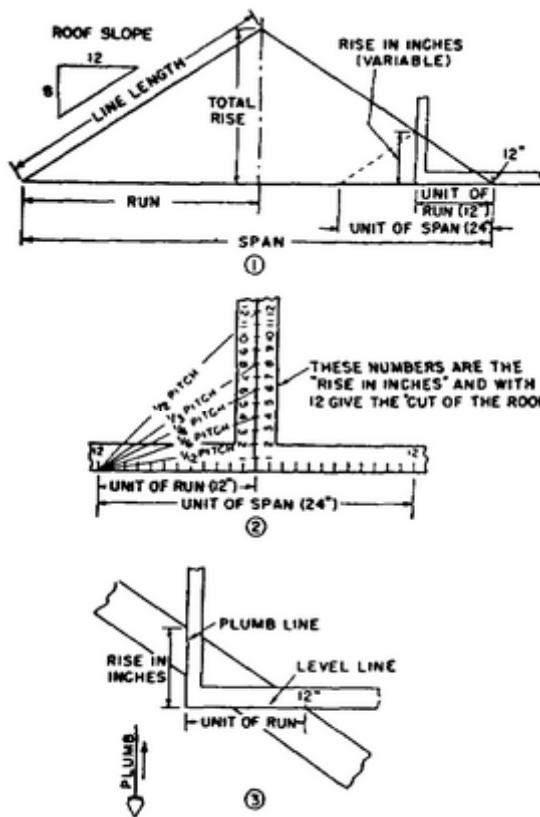


Figure 2-11. Rafter layout terms.

roof as for any other part of the building. By the use of this common unit of measurement the framing square is employed in laying out large roofs (1, 2, fig. 2-11).

(5) **Rise in inches.** The rise in inches is the number of inches that a roof rises for every foot of run.

(6) **Pitch.** Pitch is the term used to describe the ratio of rise to roof span (2, fig. 2-11).

(7) **Cut of roof.** The cut of a roof is the rise in inches and the unit of run (12 inches). See 2, fig. 2-11.

(8) **Line length.** The term line length as applied to roof framing is the hypotenuse of a triangle whose base is the total run and whose altitude is the total rise (1, fig. 2-11).

(9) **Plumb and level lines.** These terms have reference to the direction of a line on a rafter and not to any particular rafter cut. Any line that is vertical when the rafter is in its proper position is called a plumb line. Any line that is level when the rafter is in its proper position is called a level line (3, fig. 3-11).

2-5. RAFTERS

a. **General.** The members which make up the main body of the frame work of all roofs are called rafters. They do for the roof what the joists do for the floor and what the studs do for the wall. Rafters are inclined members which vary in size, depending on their length and the distance at which they are spaced. The tops of inclined rafters are fastened in one of the various common ways determined by the type of roof. The bottoms of the rafters rest on the plate member which provides a connecting link between wall and roof and is really a functional part of both. The structural relationship between rafters and wall is the same in all types of roofs. Rafters are not framed into the plate but are simply nailed to it, some being cut to fit the plate while others, in hasty construction, are merely laid on top of the plate and nailed in place. Rafters may extend a short distance beyond the wall to form the eaves and protect the sides of the building.

b. **Types of rafters and rafter cuts (fig. 2-12).** Since rafters, together with ridge-boards and

plates, are the principal members of roof framing it is important to understand the following terms that apply to them:

(1) **Common rafters.** The common rafters, AAA, extend from plate to ridge-board at right angles to both (1, fig. 2-12).

(2) **Hip rafters.** Hip rafters, DD, extend diagonally from the corners formed by intersection plates to the ridgeboard (1, fig. 2-12).

(3) **Valley rafters.** Valley rafters, CC, extend from the plates to the ridgeboard along the lines where roof slopes intersect (1, fig. 2-12).

(4) **Jack rafters.** Jack rafters never extend the full distance from plate to ridge-board. Jack rafters, BBB, are shorter than common rafters and their lower ends rest on the plate and their upper ends against the hip rafter (1, fig. 2-12).

(5) **Cripple jacks.** Cripple jacks, FF, are nailed between hip and valley rafters (1, fig. 2-12).

(6) **Top of plumb cut** is the cut made at the end of the rafter to be placed against the ridgeboard or, if the ridgeboard is omitted, against the opposite rafters (2, fig. 2-12).

(7) **Seat, bottom, or heel cut** is to rest on the plate (2, fig. 2-12).

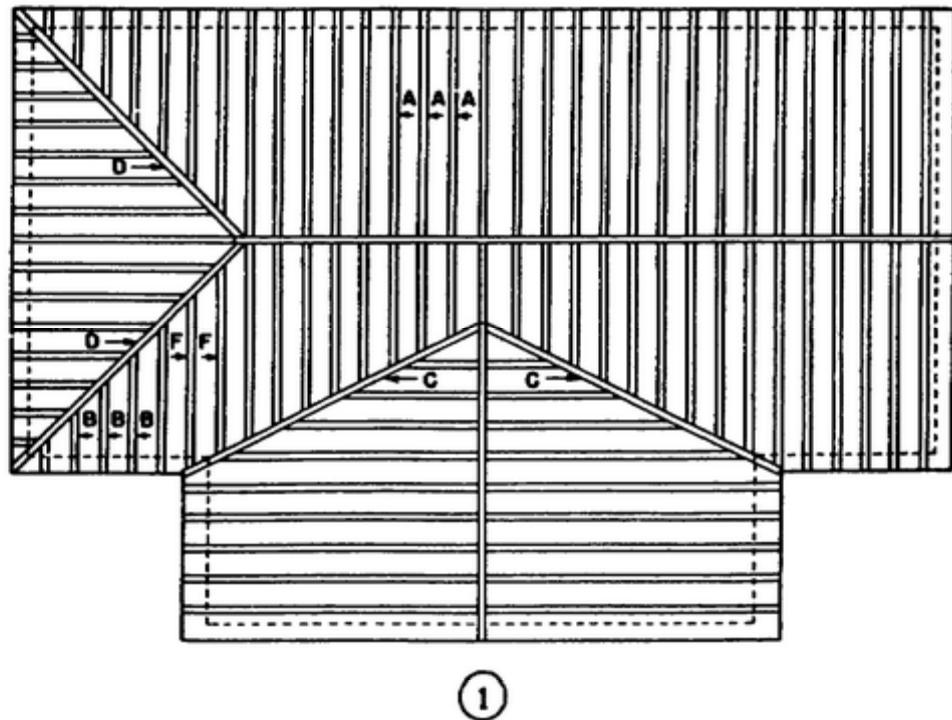
(8) **Side or cheek cut** is a bevel cut on the side of a rafter to fit it against another frame member (2, fig. 2-12).

(9) **Eave or tail** is the overhang of the rafter extending beyond the outer edge of the plate (2, fig. 2-12).

(10) **Rafter line length** is measured along the upper edge of the rafter and is the distance from the ridge line to a point marking the intersection of the upper edge of the rafter with the building limit (fig. 2-13).

2-6. RAFTER DESIGN AND LAYOUT

Rafters must be laid out and cut with slope, length, and overhang exactly right so that they will fit when placed in position. If detailed building plans are available this



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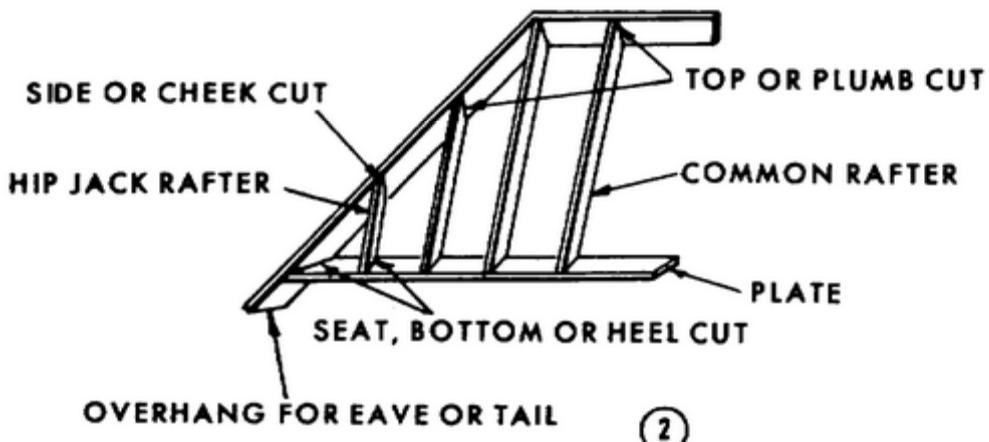


Figure 2-12. Types of rafters.

information may be obtained from them. If no plans are available, or if verification is desired, the width of the building may be measured and the roof slope determined by type of roof covering, use of building,

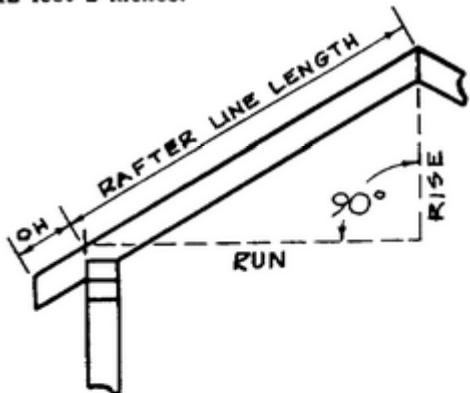
or other controlling factors. It is then possible to determine the unit run and unit rise, total run and total rise, and the rafter line length. The

rafter line length may be found either by calculation or by use of the steel square.

a. **By calculation.** The rafter line length forms the hypotenuse of a right triangle whose other sides are the total rise and the total run (fig. 2-13). It can therefore be determined by the following formula:

$$\text{Rafter line length} = \sqrt{\text{run}^2 + \text{rise}^2}$$

As an example, assume that the total run is 10 feet and the total rise is 5 feet. Then the rafter line length = $\sqrt{(10)^2 + (5)^2} = \sqrt{125} = 11.18$, or 11 feet, 2 1/6 inches. Dropping the fractional inch and adding one foot for overhang, the total length of the rafter would be 12 feet 2 inches.



$$\text{Rafter Line Length} = \sqrt{\text{RUN}^2 + \text{RISE}^2}$$

$$\text{Rafter Length} = \text{Rafter Line Length} + \text{Overhang (if Used)}$$

Figure 2-13. Typical common rafter.

b. Steel square-scaling method.

(1) It is first necessary to determine the total run and the rise in inches. Assume that you have determined a run of 10 feet and a rise of 8 inches per foot of run. To determine the approximate line length of rafter, measure on the steel carpenter square the distance between 8 on the tongue and 12 on the blade, because 8 is the rise and 12 is the unit of run. This distance is 14 5/12 inches, and represents the line length of a rafter with a total run of 1 foot and a rise of 8 inches. Since the run of the rafter is 10 feet, multiply 10 by the line length for 1

foot. The answer is 14 5/12 times 10 = 144 2/12 inches, or 12 feet and 2/12 inches. The amount of overhang must be added if an overhang is to be used (it is often 1 foot). Dropping the fraction, this makes a total of 13 feet for the length of the rafter.

(2) After the length has been determined, the timber is laid on sawhorses, sometimes called "saw benches", with the crown or bow (if any) as the top side of the rafter. Select the straightest piece possible for the pattern rafter. If a straight piece is not available, place the crown toward the person laying off the rafter. Hold the square with the tongue in the right hand, the blade in the left, and the heel away from the body, and place the square as near the upper end of the rafter as possible. In this case, the figures 8 on the tongue and 12 on the blade are placed along the edge of timber which is to be the top edge of the rafter as shown in 1, figure 2-14. Mark along the tongue edge of the square, which will be the plumb cut at the ridge. Since the length of the rafter is known to be 12 feet, measure that distance from the top of the plumb cut and mark it on the timber. Hold the square in the same manner with the 8 mark of the tongue directly over the 12-foot mark. Mark along the tongue of the square to give the plumb cut for the seat (2, fig. 2-14). Next measure off, perpendicular to this mark, the length of overhang along the timber and mark a plumb-cut mark in the same manner, keeping the square on the same edge of the timber (3, fig. 2-14). This will be the tail cut of the rafter. Sometimes the tail cut is made square across the timber.

(3) The level cut or width of the seat is the width of the plate, measured perpendicular to the plumb cut, as shown in 4, figure 2-14. Using the square, square lines down on the sides from all level and plumb-cut lines. Now the rafter is ready to be cut (5, fig. 2-14).

c. Steel square - step-off method. If a building is 20 feet, 8 inches wide, the run of the rafter would be 10 feet, 4 inches, or half the span. Instead of using the method in a above, the rafter length may be determined by "stepping it off" by successive steps with the square as shown in figure 2-15. Take the

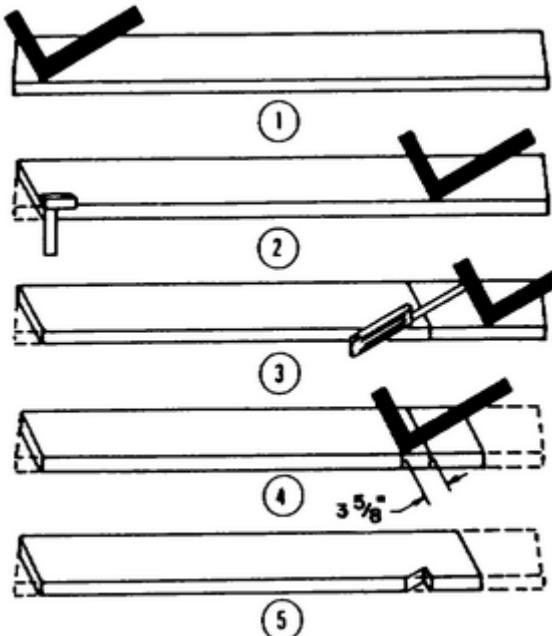


Figure 2-14. Rafter layout, scale method.

same number of steps as there are feet in the run, which leaves 4 inches over a foot. This 4 inches is taken care of in the same manner as the full foot run; that is, with the square at the last step position, make a mark on the rafters at the 4-inch mark on the blade, then move the square along the rafter until the tongue rests at the 4-inch mark (1, fig. 2-15). With the square held for the same cut as before, make a mark along the tongue. This is the line length of the rafter. The seat cut and overhang are made as described in a above (2, 3, 4, fig. 2-15). When laying off rafters by any method, be sure to recheck the work carefully. When two rafters have been cut, it is best to put them in place to see if they fit. Minor adjustments may be made at this time without serious damage or waste of material.

d. Steel square-rafter tables. The framing square may have one or two types of rafter tables on the blade. Figures 2-16 and 2-17 are illustrations of the two types. One type gives both the line length of any common rafter per foot of run and the line length of any hip or valley rafter per foot of run. The difference in length of the jack rafter spaced 16 to 24 inches OC (on center) is also shown in

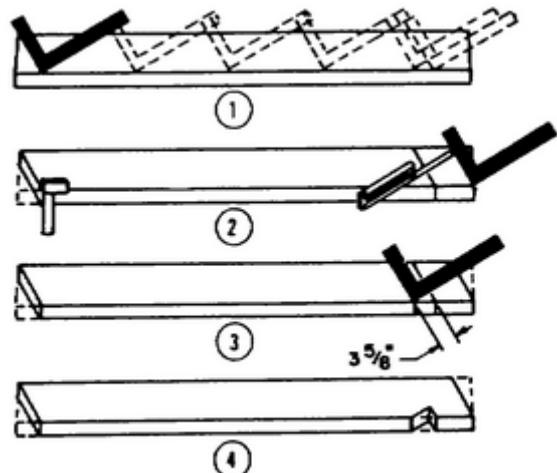


Figure 2-15. Rafter layout, step-off method.

figure 2-16. Where the jack rafter, hip, or valley rafter requires side cuts, the cut is given in the table (fig. 2-16). The other type of table (fig. 2-17) gives the actual length of rafter for a given pitch and span.

(1) The first type of table (fig. 2-16) appears on the face of the blade. It is used to determine the length of the common, valley, hip and jack rafters, and the angles at which they must be cut to fit at ridge and plate. To use the table the carpenter must become familiar with it and know what each figure represents. The row of figures in the first line represents the length of common or main rafters per foot of run, as the title indicates at the left-hand end of the blade. Each set of figures under each inch division mark represents the length of rafter per foot of run with a rise corresponding to the number of inches over the number. For example, under the 16-inch mark appears the number 20.00 inches. This number equals the length of a rafter with a run of 12 inches and a rise of 16 inches, or, under the 13-inch mark appears the number 17.69 inches which is the rafter length for a 12-inch run and a 13-inch rise. The other five lines of figures in the table will not be discussed as they are seldom used in the theater of operations.

(2) To use the table for laying out rafters, the width of the building must be

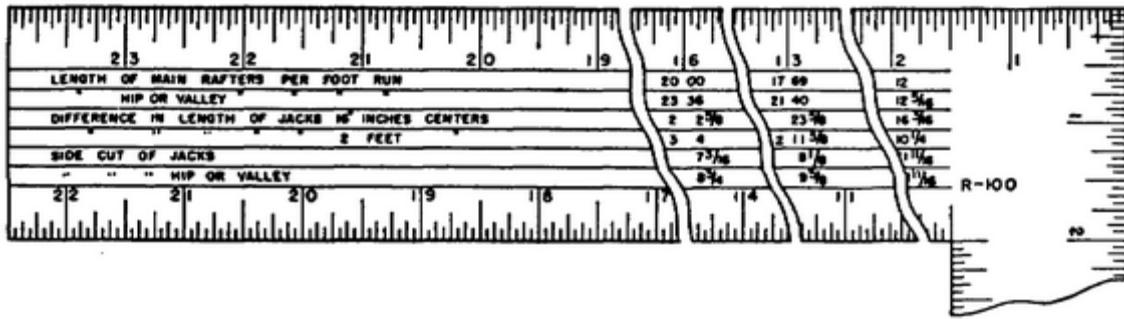


Figure 2-16. Rafter table, blade face.

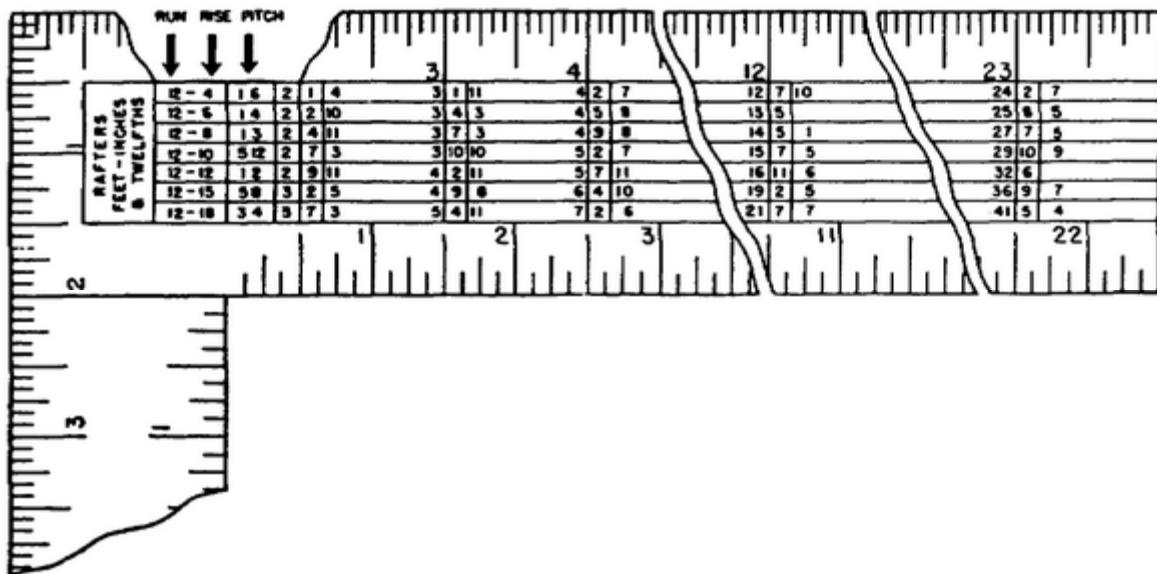


Figure 2-17. Rafter table, back of blade.

known. Suppose the building is 20 feet, 8 inches wide and the rise of the rafters is to be 13 inches per foot of run. The total run of the rafters will be 10 feet, 4 inches. Look in the first line of figures; under the 13-inch mark appears the number 17.69, which is the length in inches of a rafter with a run of 1 foot and a rise of 13 inches. To find the line length of a rafter with a total run of 10 feet, 4 inches, multiply 17.69 inches by 10% and divide by 12 to get the answer in feet. The 17.69 inches times 10% equals 182.79 inches, which, when divided by 12 equals 15 3/12 feet. Therefore 15 feet 3 inches is the line length of the rafter. The remaining procedure for laying out the rafters after the length has been determined is described in a above.

(3) The second type of rafter table appears on the back of the blades of some squares

(fig. 2-17). This shows the run, rise, and pitch of rafters of the seven most common pitches of roof (fig. 2-17). The figures are based on the length of the horizontal measurement of the building from the center to the outside. The rafter table and the outside edge of the back of the square, both the body and tongue, are in twelfths. The inch marks may represent inches or feet, and the twelfth marks may represent twelfths of an inch or twelfths of a foot. The rafter table is used in connection with the marks and figures on the outside edge of the square. At the left end of the table are figures representing the **run**, the **rise**, and the **pitch**. In the first column, the figures are all 12. These may be used as 12 inches or 12 feet as they represent the **run** of 12. The second column of figures represent various rises. The third column of figures, in fractions, represents the various pitches.

(a) These three columns of figures show that a rafter with a run of 12 and a rise of 4 has one-sixth pitch, 12 and 6 has one-fourth pitch, and 12 and 12 has one-half pitch. To use this scale for a roof with one-sixth pitch (or a rise of one-sixth of the width of the building) and a run of 12 feet, find 1/6 in the table, follow the same line of figures to the right until directly beneath the figure 12, which is the run of the rafter. Under the figure 12 appear the numbers 12, 7, 10, which is the rafter length required and which represents 12 feet, 7 inch and 10/12 of an inch. They are written as follows: 12 feet 7 10/12 inches. For a pitch of one-half (or a rise of one-half the width of the building) and a run of 12 feet, the rafter length is 16, 11, 6 or 16 feet, 11 6/12 inches.

(b) If the run is greater than 23 feet, the table in figure 2-17 is used as follows: Using a run of 27 feet, find the length for a run of 23 feet, then find the length of 4 feet and add the two. The run for 23 feet with a pitch of one-fourth is 25 feet, 8 5/12 inches. For 4 feet, the run is 4 feet, 5 8/12 inches. The total run for 27 feet is 30 feet, 2 1/12 inches. When part of the run is in inches, the rafter table reads inches and twelfths instead of feet and inches. For example, if the pitch is one-half and the run is 12 feet, 4 inches, add the rafter length of a 12-foot run to that of a rafter length of a 4-inch run, as follows: For a run of 12 feet and one-half pitch, the length is 16 feet, 11 6/12 inches. For a run of 4 inches and one-half pitch, the length is 5, 7, 11. In this case the 5 is inches, the 7 is twelfths, and the 11 is 11/12 of 1/12, which is nearly 1/12. Add it to the 7 to make it 8, making a total of 5 8/12 inches, then add the two lengths together. This sum is 17 feet, 5 2/12 inches. The lengths that are given in the table are the line lengths; the overhang must be added. After the length of the rafter has been found, the rafter is laid out as explained in **a** above.

(c) When the roof has an overhang, the rafter is usually cut square to save time. When the roof has no overhang, the rafter cut is plumb, but no notch is cut in the rafter for a seat. The level cut is made long enough to extend across the plate and the wall sheathing. This type of rafter saves material, although little protection is given to the side wall.

2-7. COLLAR BEAMS

A collar beam or tie is a piece of stock (usually 1 by 4, 1 by 6, or 1 by 8) fastened to a pair of rafters in a horizontal position part way between the top plate and the roof ridge as shown in figure 2-18. These beams keep the side walls of the building from spreading. The lower the collar beam or chord, the better it fulfills its purpose. This type of bracing is used in the roofs of small buildings where no ceiling joists are used.

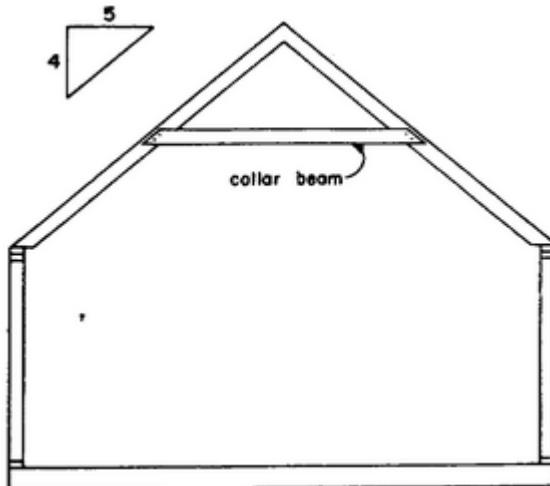


Figure 2-18. Collar beam.

2-8. TRUSS TYPE RAFTERS

a. General. Rafters will seldom be put up singly; they are usually assembled into trusses, as shown in figure 2-19. Two rafters are connected at the top by using a rafter or collar tie well nailed into both rafters. Before any ties or chords are nailed, accuracy of the rafter cuts should be checked by spreading the lower ends of the rafters to correspond to the width of the building. This may be accomplished by a template, or by measuring the distance between the seat cuts with a tape.

b. TO type trusses. Trussed rafters for a 20-foot-wide, TO type building are made from the following members (fig. 2-19).

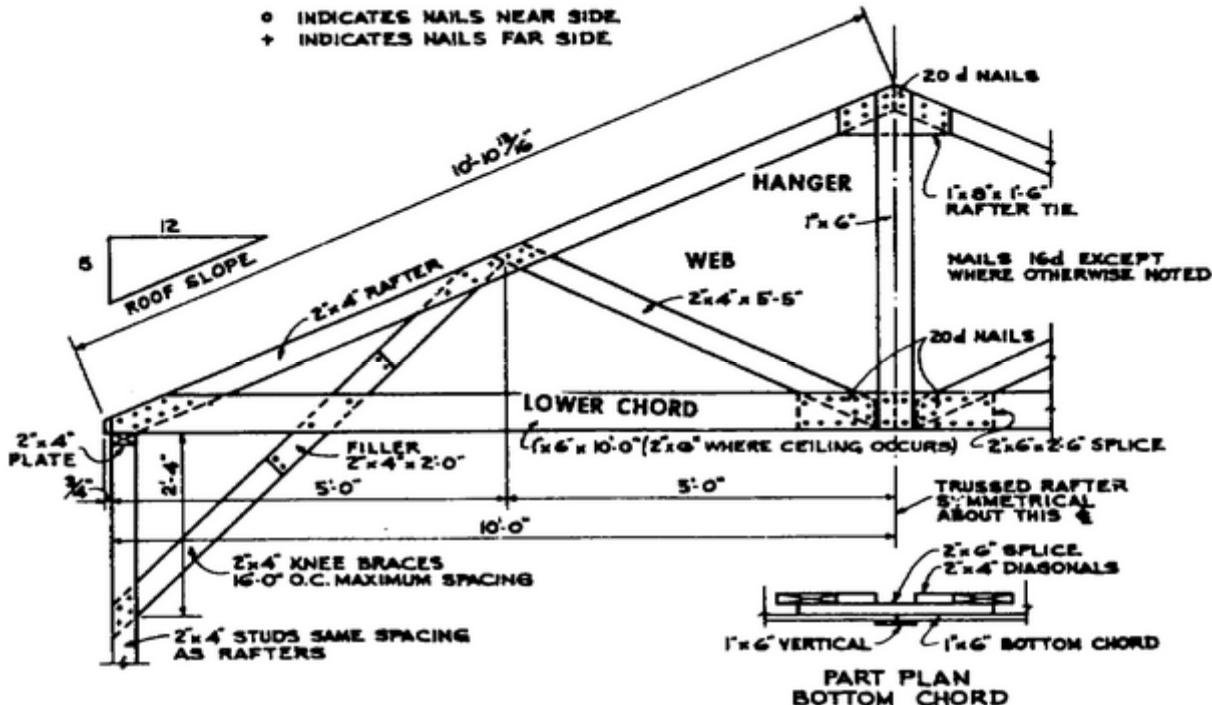


Figure 2-19. Typical rafter truss for a TO type building.

(1) Rafters. The rafters or upper chords are the same as the rafters in the end panel. Their primary function is to carry the roof load to the studs. NOTE: rafters in end panels are an integral part of the panel and are not considered as rafter trusses.

(2) Lower chord. The lower chord or ceiling joist is a 1 x 6 member spanning from the lower ends of the two rafters in the truss. When a ceiling is used, these members are increased to 2 x 6's and the ceiling is attached to them.

(3) Hanger. The hanger is the 1 x 6 vertical member in the center of the truss that ties in the peak of the rafters to the center of the lower chord.

(4) Web members. The web members are the diagonal braces which tie in the center of the lower chord with the centers of the rafters. They are cut from 2 x 4's.

(5) Rafter tie. The rafter tie, normally a piece of 1 x 8, connects the two rafters at the peak of the truss as in the end panel.

(6) Knee braces. Knee braces are the members which tie in the roof system with the wall

system. You can see that they are attached to the rafter, to the lower chord, and to the stud in the sidewall panel.

c. Advantages. The principal advantages of a trussed rafter system over a plain rafter system are that smaller size lumber can be used and that the truss can be fabricated as a unit for later erection. This results in economy of labor and material, and saves time except on very small projects.

d. Templates or jigs. Rafter framing constructed without the use of ridgeboards may be rapidly completed by use of a truss assembly jig or template. The template is laid out (1, fig. 2-20) to form a pattern conforming to the exact exterior dimensions of the truss. Templates or jigs must be constructed accurately to assure proper dimensions of the rafter truss. Lay out a jig in the following manner (2, fig 2-20):

(1) Measure and mark a straight line on a selected surface, the exact length of the joists which will form the chord of the truss. This is the base line A.

(2) From the center of the base line and at right angles to it, lay out a line the length required to form the leg of a right

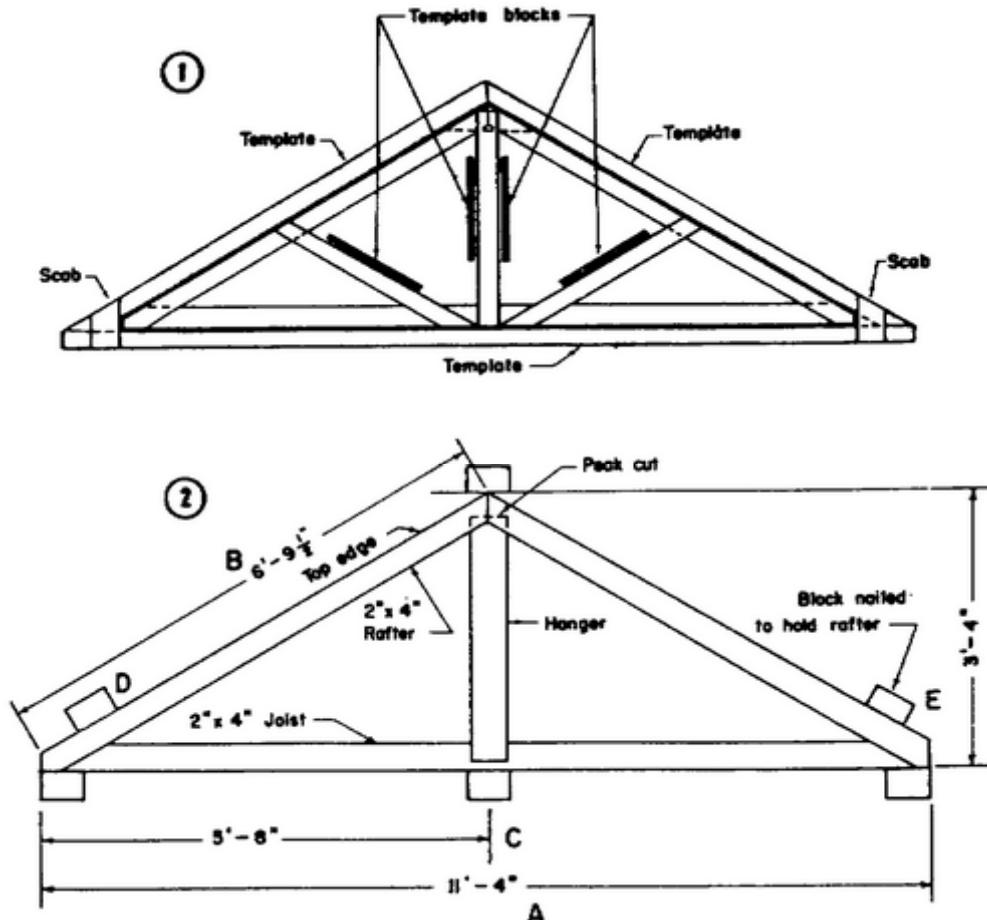


Figure 2-20. Rafter-truss jigs.

triangle, the base of which is half the length of the base line, A, and the hypotenuse, B, which is the length of the rafter measured as indicated. This is the centerline, C.

(3) Nail 2 x 4 by 8-inch blocks flush with the ends of base line A and centerline C as shown. Mark centerline on center jig blocks.

(4) Start assembly by setting a rafter in the jig with plate cut fitted over jig block at one end of base line. Peak is flush with centerline on peak jig block. Nail a holding block outside rafter at point D. Repeat for other rafter at E.

(5) Assemble trusses in the following order: Lay one 2 x 4 joist or chord in place across base blocks. Lay two 2 x 4 rafters in place over joist. Center one end of a 1 x 6 hanger under rafter peak. Center rafters against peak block. Nail through rafters into hanger with six 8-penny nails. Line up one end of chord. Nail through rafter with 16-penny

spikes. Line up other end of chord. Nail as above. Center bottom of hanger on top of chord and nail with 8-penny nails.

e. Placement. After the rafters have been assembled into trusses, they must be placed on the building. The first set of rafters may be assembled in the end section of the building or at the center as indicated in figure 2-21. The rafter trusses are raised by hand into position and nailed to the plate with 16- or 20-penny nails. These trusses are temporarily braced to the end section of the building, until the sheathing is applied. Building temporary platforms or work-benches for the workers to stand on while erecting these trusses will save time. The knee braces may be applied before or after the sheathing is applied. Knee braces are not used on every rafter truss unless severe wind conditions are anticipated. In fact, as figure 2-19 shows, they may be spaced as widely as 16 feet OC. There are several methods for

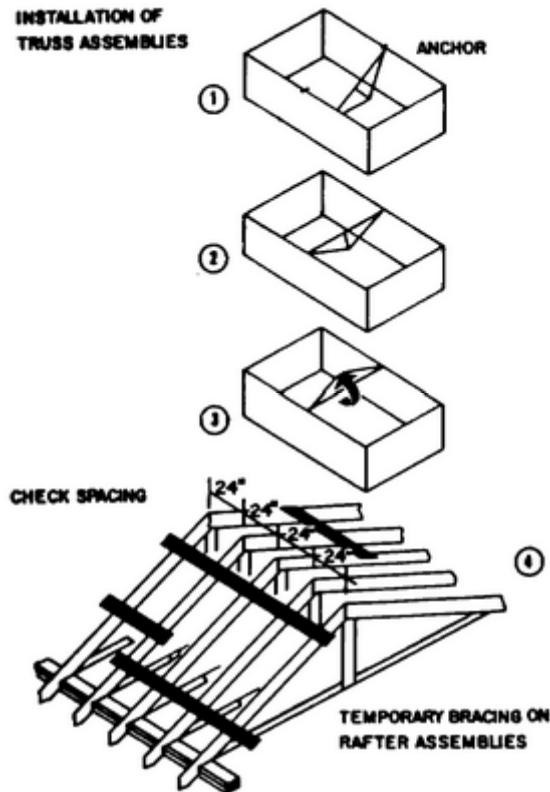


Figure 2-21. Erection of rafter trusses.

the actual installation. The following procedures may be used in the actual installation of trusses:

(1) Mark proper positions of all truss assemblies on top plate. The marks will show the exact position of a given face of all rafters (south or north, etc.).

(2) Rest one end of a truss assembly, peak down, on an appropriate mark on top plate on one side of structure (1, fig. 2-21).

(3) Rest other end of truss on opposing mark on top plate on other side of structure (2, fig. 2-21).

(4) Rotate assembly into position by means of a pole or rope (3, fig. 2-21).

(5) Line up rafter faces flush against marks and secure.

(6) Raise, align, and nail several truss assemblies into position. Nail temporary 1 x 6 braces across these assemblies (4, fig. 2-21) and other assemblies as they are brought into position. Check rafter spacing at peaks as braces are nailed on.

(7) Braces may be used as a platform when raising those trusses when there is too little room to permit rotation.

2-9. HEAVY TRUSSES

a. **Definition.** A heavy truss is a framed or jointed structure composed of straight members connected only at their intersections in such a way that if the loads are applied at these intersections the stress in each member is in the direction of its length.

b. **Types.** The web members of a truss divide the truss into a number of triangles. It is possible to arrange innumerable types of trusses, but certain types have proved to be more satisfactory than others, and each of these types has its special uses. The various types of trusses used in heavy building construction are illustrated by line diagrams in figure 2-22. The members indicated by heavy lines normally carry compressive stresses, and those indicated by light lines normally carry tensile stresses for vertical loads. In most cases, the compression members are the shortest members in the truss, while the tension members are the longest. This results in a great saving of material, for a compression member requires a greater sectional area for a given stress than does a tension member. Sometimes the top chords of these trusses are slightly sloping in one or two directions for roof drainage, but this does not change the type of truss. The necessary number of subdivisions or panels depends upon the length of the span and the type of construction.

c. **Terms used in connection with trusses.**

(1) Member is the component which lies between any two adjacent joints of a truss; it can be of one or more pieces of structural material.

(2) Bottom chord is a member which forms the lower boundary of the truss.

(3) Top chord is a member which forms the upper boundary of the truss.

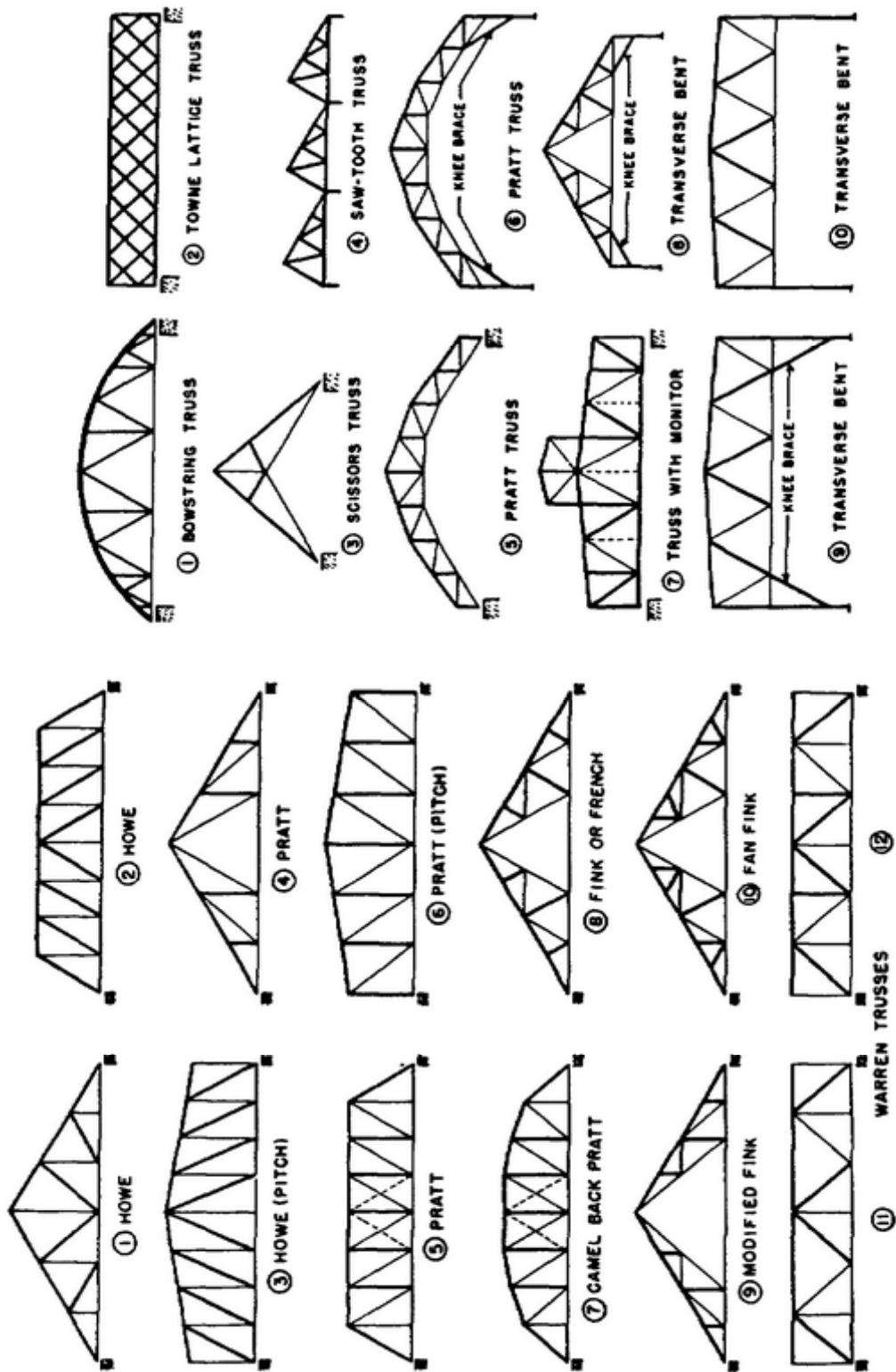


Figure 2-22. Types of trusses.

(4) Chord member is a member which forms part of either the top or bottom chord.

(5) Web member is a member which lies between the top and bottom chords. If it is vertical and at the centerline, it is also called a hanger.

(6) Joint is any point in a truss where two or more members meet and is sometimes called a "panel point."

(7) Panel length is the distance between any two consecutive joint centers in either the top or bottom chords.

(8) Pitch is the ratio of the height of truss to the span length.

(9) Height of truss is the vertical distance at midspan from the joint center at the ridge of a pitched truss, or from the centerline of the top chord of a flat truss to the centerline of the bottom chord.

(10) Span length is the horizontal distance between the joint centers of the two joints located at the extreme ends of the truss.

d. Use. Timber trusses are used for large spans to provide wide unobstructed floor space for such large buildings as shops and hangars. The Howe and Fink trusses are the ones most commonly used.

e. Truss layout and construction (fig. 2-23). The first task is to get the material to a level spot of ground where workbenches will be approximately level. Obtain from the blueprints the necessary measurements of all pieces that are to be used in the truss. Lay out the length on the different sizes of timber and cut them. Care must be taken that the lengths are cut accurately. After all the lengths of different sizes of material for a truss have been cut, lay the pieces in their correct position to form a truss and nail them together temporarily. After the truss is assembled in this manner, lay out the location of all holes to be bored, then recheck the measurements to be sure that they are correct. After this is done, bore the holes to the size called for on the print. They may be bored with a brace and bit, an electric drill, or with the woodborer which is part of a set which

accompanies the air compressor. They should be bored perpendicular to the face of the timber. After the holes have been bored, the truss is dismantled and the nails withdrawn. The assembling of a truss after it has been cut and bored is simple. In most cases, timber connectors are used where the different members of the truss join. The truss is again assembled as it was for boring holes, with the timber connectors in place. The bolts are then placed in the holes and tightened, a washer being placed at the head and nut ends of each bolt. Straight and sound timber should be used in trusses to avoid weak places.

2-10. PURLINS

Purlins are roof members that run at right angles to the rafters or rafter trusses. They are used in roof construction where corrugated sheet metal is used without sheathing, or to support the sheathing when roofs are framed with high-capacity trusses set on wide centers. In small roofs, short purlins are inserted between the rafters and toenailed through the rafters (fig. 3-2, lesson 3). In small buildings, such as barracks, mess halls, and small warehouses, 2 x 4's are used for purlins, with the narrow side up. In large-building construction, the purlins are continuous members which rest on the trusses and support the sheathing.

2-11. LIGHT THEATER-OF-OPERATIONS TYPE FRAMING

a. Plates, corners, and T-posts. TO type framing is characterized by simplicity and by economy in the use of lumber. Single rather than double top plates are used. Most TO buildings have no inside wall finish, and partitions, when used, are finished on one side only. Consequently, corners are formed by simply nailing end studs together as shown in 4, figure 2-1 and figure 24. T-posts are omitted as shown in A in 1, figure 2-3.

b. Girts. TO type framing is also characterized by widely spaced studs (spacings as wide as 8 feet OC are common) and the use of girts (fig. 2-24). Girts are horizontal members placed between studs halfway between the

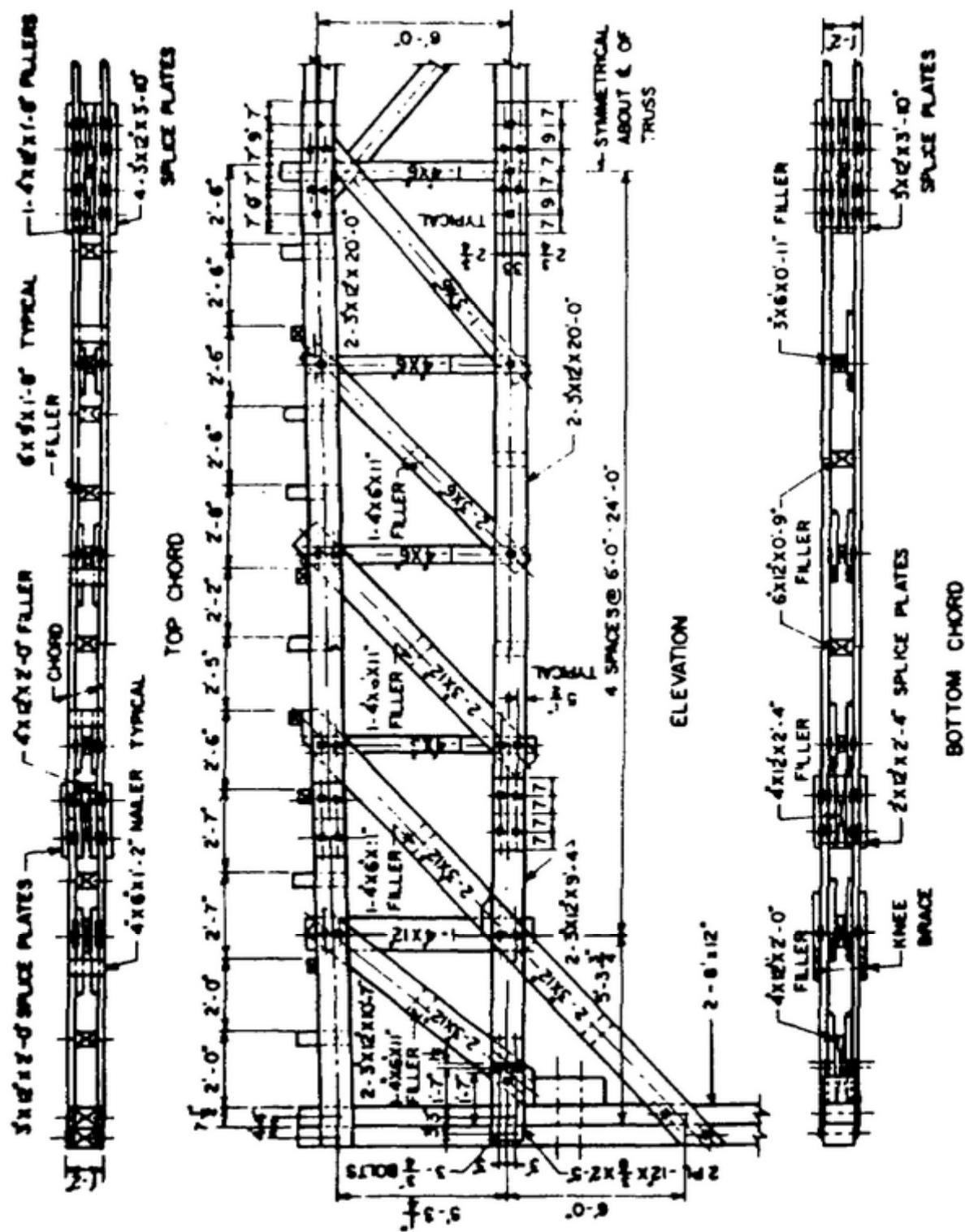


Figure 2-23. Typical heavy roof truss.

sole plate and the top plate to serve as stiffeners and nailing bases for corrugated sheet metal, outdoor plywood, waterproof composition board, and other types of vertical or large-panel siding. Note in 2,

figure 2-24, two studs are set flatwise with their outside faces flush with the outside of the sole and top plate to accommodate sliding windows. The girts are notched to take these special studs.

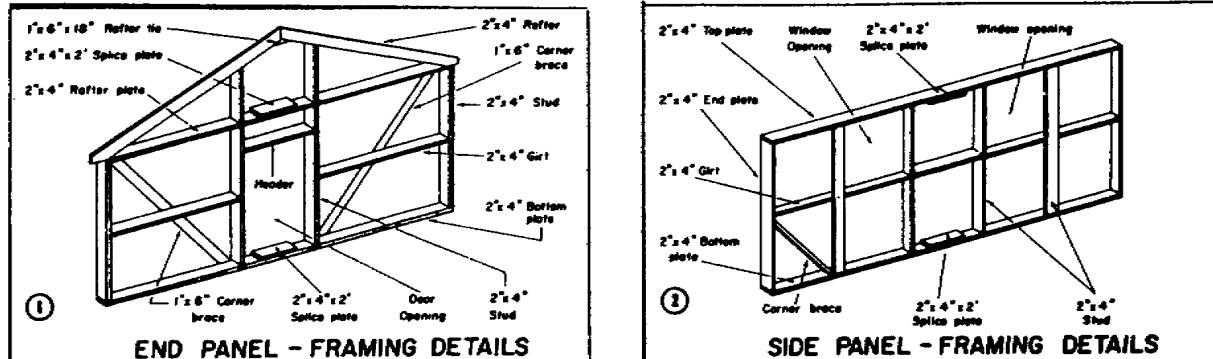


Figure 2-24. TO framing details.

SELF TEST

Note: The following exercises comprise a self test. The figures following each question refer to a paragraph containing information related to the question. Write your answer in the space provided below each question. When you have finished answering all the questions for this lesson, compare your answers with those given for this lesson in the back of this booklet. Review the lesson as necessary. Do not send in your solutions to these review exercises.

1. What structural member determines the bearing strength of stud walls? (Para 2-1)
2. Wherever a partition wall meets an outside wall, a special structural member must be used. What is it called and what is its function? (Para 2-1b)
3. For residential construction within the United States, studs are normally placed on 16-inch centers. In the more temporary TO construction studs may be placed 4 feet apart. What makes this possible? (Para 2-1d(1))
4. At what stage of the wall construction are the vertical members plumbed and the walls straightened? (Para 2-2)
5. Good diagonal bracing is essential in preventing a wall from getting out of plumb. What type of diagonal bracing is used most in TO construction where no interior finish will be applied? (Para 2-3d)
6. There are several types of roofs that can be constructed. Which type is most commonly used by the Army, and for what reason? (Para 2-4a)
7. The usual way to express roof slope is by inches of rise per 12 inches (or 1 foot) of run. If you determine from a plan or sketch that a certain roof is to rise 3 inches in 9 inches of run, convert this slope to the standard unit of run. (Para 2-4e)

8. The shortest distance between the outside edges of the outside wall plates of the side walls of a structure to receive a gable roof, is 20 feet six inches. What would be the total run in this situation? (Para 2-4f(1)(3))

9. Name the three principal structural members involved in framing a roof. (Para 2-5b)

10. When preparing to install conventional rafters in a gable roof, it is determined that many rafters have varying amounts of crown or bow. How should these rafters be installed? (Para 2-6b(2))

11. The rafter table on the back of the blade of the carpenters framing square can be used to lay out rafter cuts. Referring to figure 2-17, what is the length of rafter required if the building width is 24 feet, outside to outside, and the run to rise is 12 to 6? (Para 2-6d(3))

12. When are collar beams used and what is their function? (Para 2-7)

13. Rafters form the upper chord of TO type trusses. What is their primary function? (Para 2-8b(l))

14. Rafters are often assembled into trusses instead of being put up singly. What is the principal advantage of trussed rafters? (Para 2-8c)

15. Trussed rafters eliminate the need for one structural roof member essential when rafters are installed, singly. What is this member called? (Para 2-8d)

16. Knee braces are the structural members that tie the roof system to the wall system. Spacing of knee braces may vary under different conditions. Explain briefly. (Para 2-8e)

17. In a heavy truss why is it generally designed so that compression members are shorter than tension members? (Para 2-9b)

18. In the construction of a heavy truss what actions are taken before the joint holes are bored? (Para 2-9e)

19. What is the difference in the installation of purlins for large roofs and small roofs? (Para 2-10)

20. Simplicity and economy are the key words in TO construction. How is economy in the use of studs frequently accomplished? (Para 2-11b)

LESSON 3

ROOFING-FINISHING DETAILS

CREDIT HOURS.....	2
TEXT ASSIGNMENT.....	Attached memorandum.
MATERIALS REQUIRED.....	None.
SUGGESTIONS.....	Review lesson 1.

LESSON OBJECTIVES

Upon completion of this lesson you should be able to accomplish the following in the indicated topic areas:

1. **Roofing.** Design and supervise the installation of roofs for any typical theater-of-operations type building.
2. **Finishing details.** Plan and supervise the finishing details for both interior and exterior

walls of a structure utilizing the materials most suitable under the prevailing circumstances.

3. **Stairs.** Design and construct stairs for theater-of-operations type buildings.
4. **Fire prevention.** Determine appropriate measures to obtain adequate protection against the hazards of fire.

ATTACHED MEMORANDUM

3-1. PLYWOOD

a. Plywood is a timber product frequently used in frame structures. It consists of wood panels, usually made up of three or more thin layers glued together, with the grain of adjacent layers at an angle, usually 90°, to each other. It may be made up of veneer lumber or various combinations of veneer and lumber. Plywood used in TO construction is usually 5/16", 3/8", 1/2", or 5/8" thick and composed of three or five plies of veneer. Depending upon the type of adhesive used in manufacture, plywood is also rated as nonwater-resistant, water-resistant, or waterproof.

b. Compared with solid wood, plywood has the advantages of approaching equalization of strength along the length and width of the panel, greater resistance to checking and splitting, and less change in dimension with change in moisture

content. Also, since it comes in large panels (usually 4 by 8 feet), it can be installed with less labor and provides more bracing effect than ordinary lumber.

3-2. FINISHING MATERIALS

a. Glass (or window pane) is sometimes available for TO construction in either single- or double-strength panes. Since glass is difficult to ship and requires special handling, several substitutes have been developed. One of the most common glass substitutes furnished for TO construction purposes is a clear, flexible, plastic which comes in rolls and is cut to the size required as it is used.

b. Several types of fiberboard and insulation board are manufactured and are used for finishing ceilings and the inside walls of

buildings. These materials are frequently referred to as "wall board." They are normally stocked at depots and are component parts of many of the issue prefabricated buildings.

3-3. ROOF SHEATHING

a. All flexible roof coverings such as roll roofing and asphalt shingles require a continuous supporting surface. Rigid, large-panel roofing materials, such as corrugated sheet metal and asbestos boards do not require continuous support except that, in extremely cold climates, solid sheathing is recommended for its insulating value.

b. Wood sheathing should be seasoned wood ranging in nominal size from 1 x 4 to 1 x 8. If the roof is sheathed solid the sheathing may be square edged, tongued and grooved, or shiplapped. It should be surfaced on both edges and at least one side. It should be nailed with two or more 8-penny nails to studs or rafters. Joints are made on the rafters and are staggered to prevent weak spots in the roof. After the roof has been sheathed, cutting lines are marked by snapping a chalkline. Then the ends of the sheathing are cut off smooth, preferably with a power saw, leaving the correct amount of overhang. If there is no overhang the cut in made flush with the outside edge of the end rafter.

c. Where corrugated sheet metal or other strong, large-panel material is used for roof covering, slatted sheathing may be used as an economy measure if extra insulation is not required and if the rafter spacing is moderate. "One-in-three" spacing, in which the spaces left between the sheathing boards are twice the width of the boards (fig. 3-1), is common practice. Where rafters are very widely spaced (2 feet on centers (OC) and wider) the use of 2 x 4 purlins set flush with the tops of the rafters and spaced 1 to 3 feet apart (fig. 3-2) is preferable to slatted sheathing for corrugated metal.

3-4. TYPES OF ROOFING

Of the many types of roof covering which are used, this subcourse covers only the types used by the Army in the theater of operations;

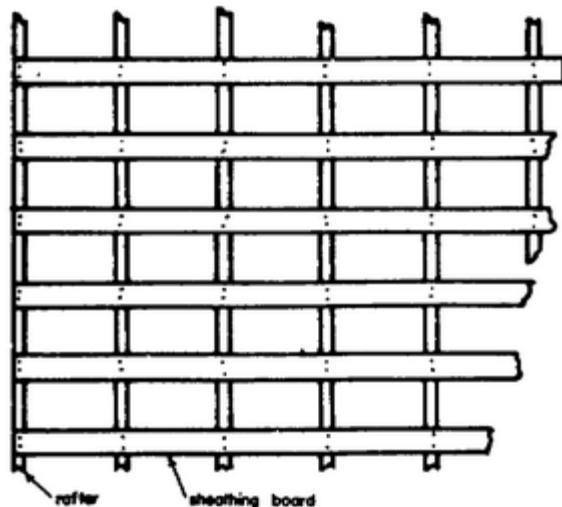


Figure 3-1. Slatted sheathing.

corrugated sheet metal and prepared roofing.

a. **Corrugated sheet-metal roofing.** Standard corrugated sheet-metal covering has corrugations 2 1/2 inches wide and 5/8 inch deep. The sheets are 26 inches wide and vary in length from 6 to 12 feet. If steel they are either painted or galvanized to prevent corrosion. Corrugated aluminum requires no coating.

b. **Prepared roofing.** There are several brands of prepared roofing, a similar in type. They are composed of either paper, felt, or asbestos paper, and are saturated with different brands of waterproofing compounds. They are assembled at the factory, along with roofing nails and asphalt cement, into strips about 1 yard wide and 12 yards long. The roofings used in TO construction usually have a plain surface treated with sand, mica, or talc to prevent sticking. Other mineral surfacing includes slate and ceramic granules.

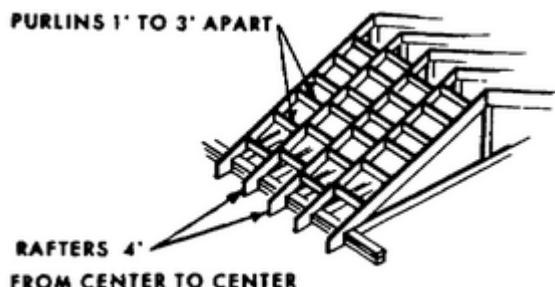


Figure 3-2. Purlins.

This type of roofing is furnished in rolls and is sometimes called "roll roofings." TO structures are normally roofed with a paper weighing 40 pounds per roll; for wall coverings a 15-pound asphalt felt is standard.

3-5. ROOFING INSTALLATION

a. **Corrugated roofing.** Corrugated sheet iron may be nailed to either solid or slatted wood sheathing, or to wood purlins. The sheets are overlapped one or two corrugations on the sides and 6 or 8 inches on the ends, depending upon the slope of the roof. To nail this type of roofing securely, a special type nail should be used, such as lead-headed nail or a galvanized nail with a neoprene washer. Common wire nails may be used but they rust easily and may cause slight leaks. The side laps should be nailed every 2 feet, while the end laps should be nailed every foot. This type of roofing should not be used on roofs with slopes of less than 4 inches per foot.

b. **Prepared roofing.** Prepared roofing is nailed to solidly sheathed roofs with special nails and asphaltic material that are normally furnished with the roofing. These nails have large, flat heads and are used on edge and end laps 3 inches on centers. All laps are cemented with asphalt or tar before being nailed. Prepared roofing may be laid parallel to the roof slope, but it is somewhat less likely to leak when the strips run parallel to the eaves. In TO construction this type of roofing should be laid with an -inch end lap and with a 4-inch edge or side lap on slopes of more than 2 inches per foot. If used on flatter slopes, at least a 6-inch edge lap must be used and great care must be taken to have all joints fully cemented. All roof slopes of less than 1 inch per foot are unsuitable for prepared roofing and require multilayer, built-up roofing. Because of the wide laps used by the Army and allowances for jobcut flashings, a **40-pound roll (or "square") of prepared roofing will cover only 80 square feet in TO construction.** Rolls of 15- and 30-pound felt cover 320 and- 160 square feet, respectively.

3-6. ROOF FLASHINGS

Where two roofs come together at angles, a valley is formed and some type of additional covering must be used along the joint to provide adequate waterproofing. A hasty and yet satisfactory expedient is to use two layers of roll roofing in the valley, one 14 inches and the other 22 inches wide, both cut from a 36-inch width of material. A strip of sheet metal 22 inches wide may also be used (1 and 2, fig. 3-3;). The metal or roll-roofing material used to cover the joining roofs is cut back from the center of the valley 3 or 4 inches, as shown in 1 and 2, fig. 3-3. The joint formed when a roof butts against a vertical wall is flashed as seen in 3 and 4, fig. 3-3. Metal or roll roofing may be used as the flashing. If the vertical wall is not sheathed, a girt is installed between the studs (4, fig. 3-3), to support the flashing.

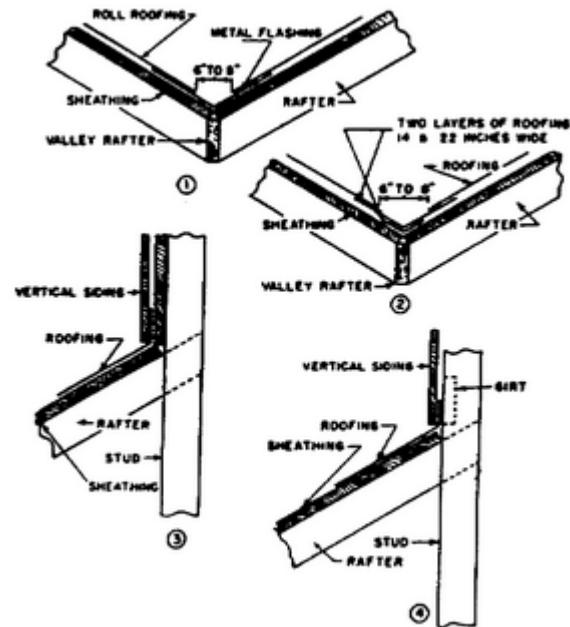


Figure 3-3. Flashing details.

3-7. HOOD

The hood or canopy is used in tropical climates to afford protection to the screened opening at the ends of the buildings. Hoods are framed to the end walls with short rafters which are nailed to the building with knee braces, as shown in figure 3-4. The rafters

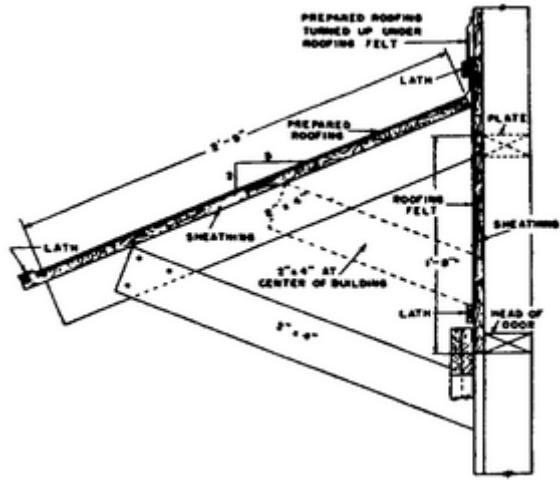


Figure 3-4. Typical hood or canopy.

are nailed to the wall, the bottom edge flush with the bottom of the end plate. The rafter and braces are 2 x 4's nailed with 8- or 10-penny nails. The sheathing is the same material as the roof sheathing and is covered with roll roofing. The hood should extend about 2/ to 3 feet from the building.

3-8. ROOF FINISH

a. The lines in which the sloping roof meet the vertical wall are called the eaves. In TO construction, eaves are usually finished as shown in 1 and 2, fig. 3-5. This method is the most efficient and should be used wherever possible. The roof should have an overhang at the eaves. The length of overhang will depend upon the climatic conditions and amount of protection required. The spaces between the rafters on top of the plate should be dosed with boards.

b. Where rafters have no overhang the first piece of sheathing is placed on the rafters so that it hangs over the rafters 3 to 4 inches. A fascia board is placed under the sheathing and nailed to the rafter ends to close the opening between the rafters. This board should be at the minimum a 1 x 4.

c. At the ridge of the roof where two slopes meet, provision must be made to finish the covering so that it will not leak. When roll roofing is used, the finish can be made as in 3 and 4, fig. 3-5. This is the simplest

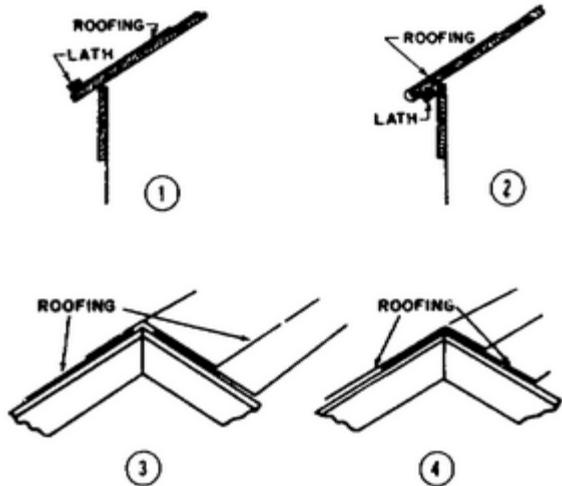


Figure 3-5. Types of eave and ridge finish.

method and promotes efficiency and conserves time. On the ends of the roof ridge the roofing may be rolled around the edge of the sheathing and back on the under side far enough so that a 1 x 2 strip can be nailed underneath to hold the roofing, or it may be cut flush with the end of the sheathing and the strip nailed flush with the edge to hold the roofing. When corrugated sheet metal is used, the metal should overhang the sheathing from 1 to 2 inches. The sheathing may overhang on the gable ends as it does on the eaves to provide added protection to the walls.

d. If the sheathing does not overhang the gables, it should end at the rafters edge. The wall sheathing should end at the top edge of the rafter. The roofing is lapped over the end of the rafters by a minimum of 3 inches and fastened by a 1 x 4 nailed over the roofing along the gable with the top edge of the board even with the top of the rafter.

3-9. EXTERIOR WALL FINISHES

a. General. The exterior surfaces of a building usually consist of vertical or horizontal sheathing and composition or corrugated sheet-metal roofing. However, in TO construction the materials prescribed by typical plans are not always available, and substitutes or improvised materials must be provided from local sources. Concrete block,

rubble stone, metal, or earth may be substituted for wood in treeless regions. In the tropics, improvised siding and roofs can be made from bamboo and grasses. Roofing felt sandwiched between two layers of light wire mesh may serve for wall and roof materials where the climate is suitable.

b. Vertical sheathing. Vertical sheathing consists of 1-inch nominal-thickness boards, usually 6 inches or more in width, nailed with 8- or 10-penny nails at top and bottom to the plate and sole plate and in the middle to the girts. Vertical sheathing requires less framing lumber than horizontally applied siding since the vertical sheathing helps support the roof load on the top plate. Cracks between the boards may be covered with narrow wooden strips called "battens", or some type of light roll roofing, tar paper, or asphalt felt may be applied over the entire surface and fastened at the seams with roofing nails or with laths or light battens.

c. Siding. Siding may be classified into three types: beveled siding, drop siding, and Shiplap. It is applied horizontally and nailed to studs with two or more 8- or 10-penny nails. To make this siding more weatherproof, building paper may be used on the studs and nailed either to the siding, after it has been applied, or between the sheathing and siding if sheathing is also used. The methods of application for the different types are similar. Drop and shiplap siding have a rabbeted edge to give the proper lap. The lap must be measured each time in applying the beveled siding, which requires much time. In TO construction, siding, when used, will normally be applied alone without the back-up layer of wood or other sheathing customarily found in permanent construction.

d. Use of corrugated iron. Corrugated sheet iron is used extensively as wall coverage since little framing, time, and labor are needed to install it. It is applied vertically and nailed to girts, the nails being placed in the ridges. Sheathing may be used behind the sheet iron with or without building paper. Since asphaltic felt or tar paper used behind sheet iron will cause the metal to rust, a resin-seized paper should be used.

e. Other large-panel wall finishes. Other

large-panel, rigid wall finishes that are often applied to framing characterized by widely spaced studs supplemented by girts include exterior grade plywood, tempered hardboard, gypsum board, and treated fiberboard. Characteristics are, briefly, as follows:

(1) Plywood. As stated previously, the standard plywood panel is 4 by 8 feet, but plywood may occasionally be issued in 6-, 9-, 10-, and 12-foot lengths.

(2) Hardboard. Hardboard is a very dense, tough, grainless material made from highly compressed wood fibers. It is furnished in "ordinary" which is water-resistant, and "tempered" which is waterproof. It comes in 1/8" and 1/4" thickness and in the same widths and lengths as plywood.

(3) Gypsum board. This is 1/2-inch thick, 24 and 48 inches wide, and 8, 9, 10, and 12 feet long. It consists of a gypsum core cast in a heavy water-resistant fiber envelope. The long sides are normally tongued and grooved. It does not warp or absorb water.

(4) Fiberboard. Fiberboard is usually made from sugarcane refuse (bagasse) and treated with asphalt. It comes 25/32-inch thick, 24 and 48 inches wide, and 8, 9, 10, and 12 feet long.

f. Building paper. Building paper is of several types, the most common being the nonwaterproof resin-seized papers.

(1) Resin-seized papers are usually red or buff but sometimes blue in color. They are usually put up in rolls 36 inches wide containing 500 square feet and weighing from 18 to 50 pounds per roll. Conventionally, this type of paper is applied between the sheathing and the siding or other external wall finish. In consequence, it is of limited usefulness in TO construction which is characterized, in the main, by single-layer wall construction.

(2) Tar- and asphalt-treated papers are frequently used in temporary TO construction as final protective wall finish. Tar papers are usually furnished in rolls containing 500 square feet; asphalt felts in rolls of 216 or 432

square feet. All are usually 36 inches wide and black in color.

3-10. INTERIOR FINISHES

a. Wallboard. Interior walls and ceilings are not normally finished in TO construction. When they are, it is usually done with one of the several types of wallboard that may be carried in depot stock, or furnished with prefabricated buildings. Most common of these wallboards are plywood, plaster board, and fiber board. The most common size for wallboard is 4 feet by 8 feet by 1/2 inch thickness, but some are available in lengths up to 12 feet and in 1/4 to 1 or more inches in thickness. This type of material requires a minimum of labor time and in some cases will provide greater structural strength with less materials, than other types of interior finish materials.

b. Plaster and wood. Other methods of interior finish may be used, depending upon materials and labor available. Wet walls, generally plaster, are normally not used in the TO because of lack of skills and materials and the curing time required. Dimension lumber if available, will provide an excellent finish. Installation of this material, sometimes called ceding lumber, is either horizontal or vertical depending upon framing used in the structure (fig. 3-6).

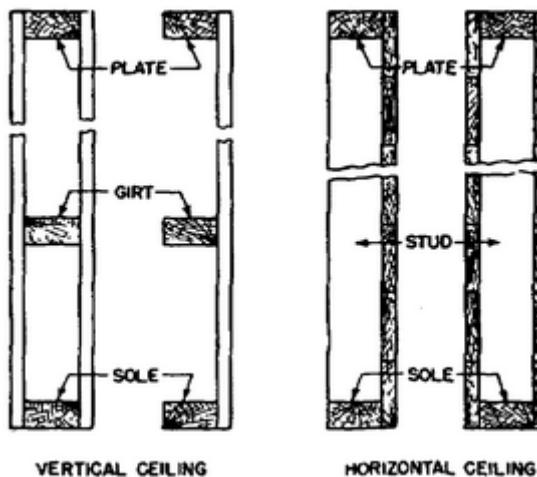


Figure 3-6. Partition-wall finishes.

c. Door frames.

(1) Outside door frames are constructed in several ways. In most haste construction the frames will be as shown in figure 3-7. This type requires no framing because the studs on each side of the opening act as a frame. The outside finish is applied to the wall before the door is hung. The casing is then nailed to the sides of the opening and is set back the width of the stud. A 3/4 x 3/4 piece is nailed over the door to act as a support for the drip cap and is also set back the width of the stud. Hinge blocks are nailed to the casing where the hinges are to be placed. The door frame is now complete and ready for the door to be hung. Figures 3-7 and 3-8 show the elevation and cross section of a single and double outside door frame.

(2) Inside door frames, like outside frames, are constructed in several ways. In most TO construction the type shown in figure 3-9 will be used. The interior type is constructed like the outside type except that no casing is used on inside door frames. Hinge blocks are nailed to the inside wall

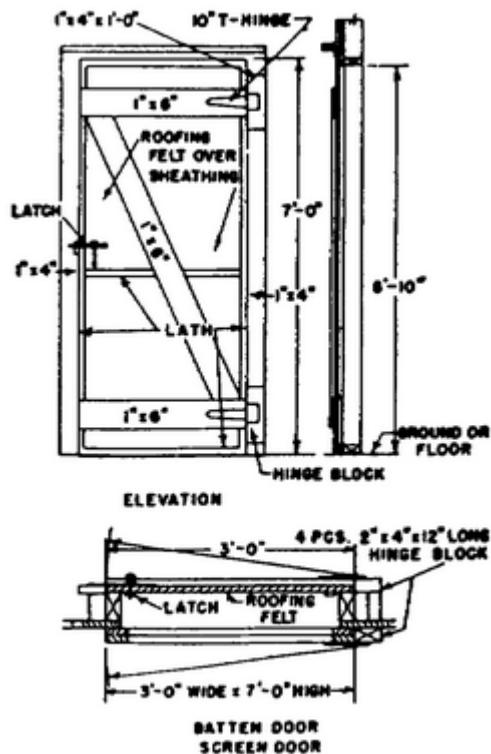


Figure 3-7. Single outside door.

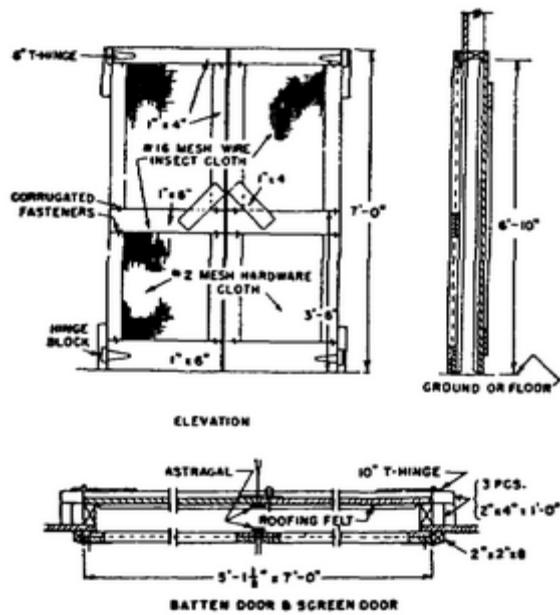


Figure 3-8. Double outside door.

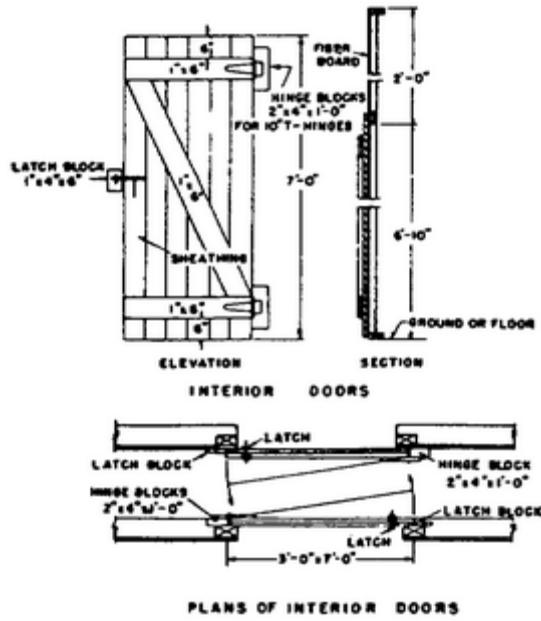


Figure 3-9. Single inside door.

finish, where the hinges are to be placed to provide a nailing surface for the hinge flush with the door. Figure 3-9 shows the elevation, section and plan of a

single inside door. Both the outside and inside door frames may be modified to suit climatic conditions.

d. Doors. In TO construction, the carpenter who erects the building usually makes the doors from several boards with battens and braces as shown in figure 3-7. These boards are 1 x 6's, laid close together and nailed to battens. The battens are placed with their edges 6 inches from the ends of the door boards. A brace is placed between the battens, beginning at the top batten end opposite the hinge side of the door, and running to the lower batten diagonally across the door. These battens and braces are well nailed. If the door is used as an outside door, roofing felt is used to cover the boards on the weather side. The battens and braces are nailed over the felt. Wooden laths are nailed around the edges, top, bottom, and sides, and across the middle of the door to hold the roofing felt in place. The battens and braces on doors are of 1 x 6's and are nailed securely to the door boards. In hanging these doors, T-strap hinges are used. The hinges are fastened to the battens of the door and to the hinge blocks on the door casing or post. One-quarter of an inch clearance should be left at top, bottom, and latch side of the door to take care of expansion.

e. Window frames. In TO construction, millwork frames are seldom used. The window frames are mere openings left in the walls with the stops all nailed to the stud. The sash may be hinged to the inside or the outside of the wall, or constructed so as to slide. The latter type of frame is the most common in Army construction as it requires little time to install. Figure 3-10 shows the section and plan of a window and window frame of the type used in the field. After the outside walls have been finished, a 1 x 3 is nailed on top of the girt at the bottom of the window opening to form a sill. A 1 x 2 is nailed to the bottom of the plate on the side studs and acts as a stop for the window sash. A guide is nailed at the bottom of the opening flush with the bottom of the girt, and one nailed to the plate with the top edge flush with the top of the plate. These guides are 1 x 3's, 8 feet long. Stops are nailed to the bottom girt and plate between the next two studs, to hold the sash in position when open.

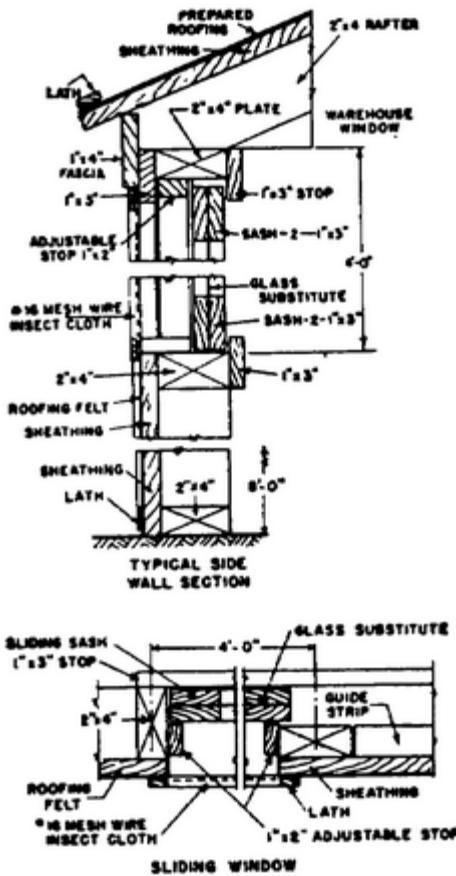


Figure 3-10. Detail of wall section with window frame and sash.

f. Window sashes. A sash can be made of 1 x 3 material, with glass substitute installed as shown in figure 3-11. Glass substitute is obtained in rolls, like screen wire or roll roofing, and can be cut to any desired size with a sharp-edged tool. Two frames are made with the glass substitute installed on one; the two frames are then nailed together. In making these frames the side pieces are all cut the same length, the length being the height of the sash less the width of one piece of material. The top and bottom pieces are cut the same length as the window, less the width of the material. They are fastened at the joints with corrugated metal fasteners. When the two frames are nailed together, one should be turned end for end so that the joints are not over each other. This staggers the joints and gives the sash more strength. If the sash is too large for the glass substitute to cover, a muntin (wood strip) may

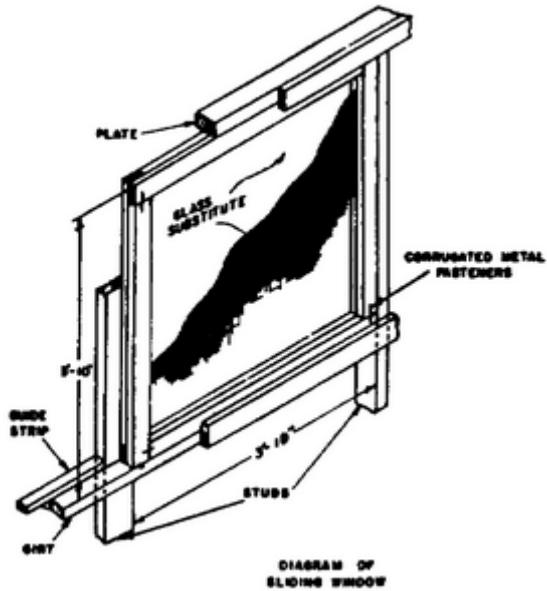


Figure 3-11. Window frame and sash detail (sliding window).

be placed in the sash to hold the glass substitute and should be fastened with corrugated metal fasteners.

g. Window and door details. Door and window details normally show sectional views of the jamb (the side piece or frame of the opening) as well as of the head and sill (the top and bottom portions respectively of the window and door frames). It is also customary to give an elevation view of the doors and window sash.

h. Wainscoting. Wainscoting is installed at the bottom 3 or 4 feet of plaster board, fiber board, or other finish walls which are continuously subject to damage by hard usage. It may be constructed of wood, plywood, or a tempered (hard) fiber board. (fig 3-12)

i. Flooring. A finish floor in the theater of operations, in most cases, is of 3/4-inch material, square edged or tongued and grooved, and varying from 3/4 to 7 1/4 inches wide. It is laid directly on floor joists or on a subfloor (perpendicular to the joists) and nailed with 8-penny cut nails in every joist. If these nails are not obtainable, 8-penny common nails may be used. When wide flooring is used, it should be face nailed in every joist.

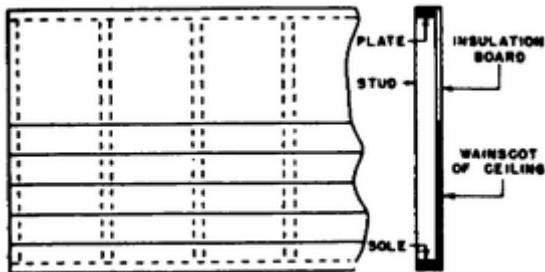


Figure 3-12. Wainscot installation.

When laid on a subfloor, it is best to use building paper between the two floors to keep out dampness and insects. In warehouses, where heavy loads are to be carried on the floor, 2-inch material should be used. The flooring is face nailed with 16- or 20-penny nails. It is not tongued and grooved and it ranges in width from 4 to 12 inches. In all cases, unless there is subflooring, the joints are made on the centers of the joists.

j. Hardware.

(1) The term "hardware" is used to designate locks, hinges, sash cord, weight, pulleys, checks, pulls, fasteners, etc. These items are divided into two classes, rough hardware and finish hardware.

(2) Rough hardware includes such items as padlocks, used to fasten doors; strap hinges, used to hang doors and other items; sash cord, weights, and pulleys, used for double-hung windows; track assemblies for sliding or rolling doors; and screen wire used for protection against insects. In most cases all these items are easily installed. In the theater of operations, hinges and screen wire are the most common hardware.

(3) Finish hardware includes mortise and rim locks, butt hinges, door checks, and window pulls.

k. Screens. Screens are placed on door and window openings. These screens are made and installed at the jobsite. Door screens are made as shown in figure 3-8. Two separate frames are made of 1 x 4 material for the sides and top, and 1 x 6 material for the bottom and middle pieces. This frame is put together with corrugated metal fasteners, then the screen wire is applied. The second frame is

made with the crosspiece the full width of the door. The side pieces are cut to correspond with the distance between the crosspieces. The second frame is placed over the first frame and nailed securely. For push-and-pull plates, two short braces of 1 x 4's are nailed to the side opposite the hinge side.

3-11. DESIGN OF THEATER-OF-OPERATIONS STAIRS

a. General. In large multistory buildings, stair design becomes an involved problem, but in a single-story TO frame building the problem is simply to get a good stair from the ground to the platform. The platform is usually located outside the exterior door. In the TO stairway the primary structural members are the stair stringers or carriages which are 2 x 12 members spaced 2 feet on centers. In properly designed stair stringers a definite relationship exists between the riser, a vertical part of the stairs, and the tread, a horizontal part. One dimension, always known as the total rise, is the vertical height of the flight of stairs or the distance from the top of the platform to the ground. The total **stringer** rise is always one riser less than the **total** rise because one riser is provided by the platform framing. The rise of stairs is illustrated in figure 3-13.

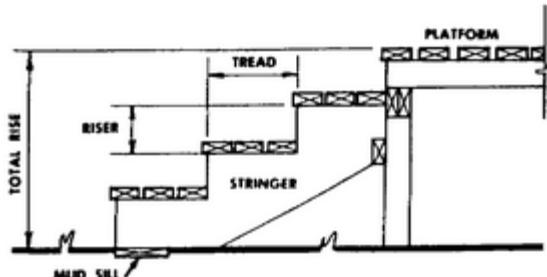


Figure 3-13. Rise of stairs.

b. Determining dimensions of risers and treads. There are two rules of thumb that may be used to determine the dimensions of risers and treads. They are:

$$\text{Riser} + \text{tread} = 17 \text{ to } 19 \text{ inches}$$

$$\text{Riser} \times \text{tread} = 70 \text{ to } 75 \text{ inches}$$

If the sum and the product of the riser and tread fall within these limits, the stair design is satisfactory. Riser dimensions usually fall

between 6 1/2 and 9 1/2 inches; treads between 8 and 11 inches.

c. **Application.** To illustrate the application of these rules of thumb, let us take the problem of determining the dimensions and number of risers and treads required for the outside stairs of a TO building with a total rise of 25 inches.

(1) If we assume a 6 1/2-inch height for the riser, $\frac{25}{6.5}$ or 3.84 risers are required.

Since a whole number of risers must be used, we will use 4. If 4 risers are to be used, each must have a dimension of $\frac{25}{4}$ or 6 1/4 inches.

(2) Utilizing the first rule of thumb, riser plus tread = 18 inches, then the tread = 18 inches minus riser. In this case the tread dimension will be 18 inches less 6 1/4 inches or 11 3/4 inches.

(3) Next check the dimensions by the second rule of thumb, riser times tread = 70 to 75. In this instance, 6.25×11.75 , or 74.4. Since this value is between 70 and 75, the stair design is satisfactory. Figure 3-13 shows the regular progression of steps from ground to platform level in the stairs designed.

3-12. STRINGER LAYOUT

a. The framing square is normally used in the layout of stair stringers. To illustrate its use for this purpose let us take the problem to laying out the stringers for the stairs shown in figure 3-13.

b. Figure 3-14 shows how the completed stringer will look. The stringer itself has only three risers, the fourth riser being provided by the platform framing. The 6 1/4-inch dimension of the first or bottom riser is measured from the ground to the top of the 1/2-inch-thick tread (actual thickness of 2 x 4 stock). Each of the other 6 1/4-inch dimensions is measured from the top of one tread to the top of the next tread. The first riser in the stringer is therefore 6 1/4 less 1 1/2, or 4 3/4 inches. The other two risers are the full 6 1/4 inches.

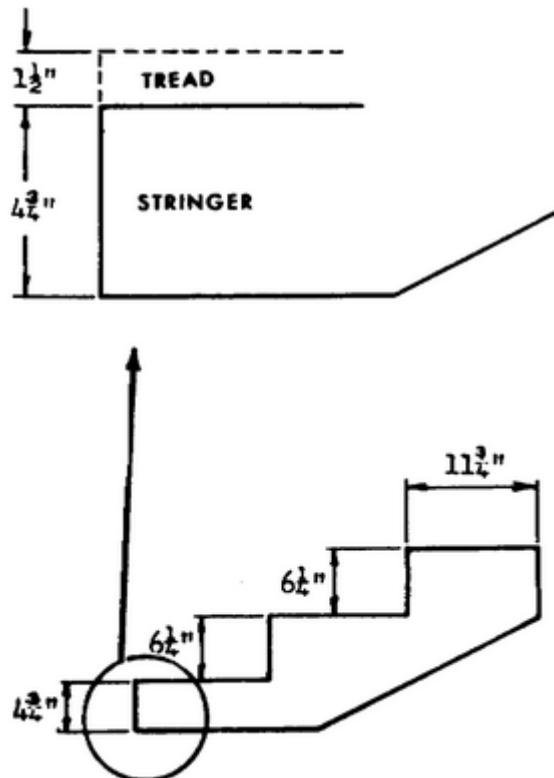


Figure 3-14. Stringer dimensions.

(1) Starting with a 2 x 12 and a framing square, the stringer can be laid out in the same manner as a rafter, by using 6 1/4 inches as the rise and 11 3/4 inches as the run. The first mark will be made in the manner shown in figure 3-15. Line A indicates the

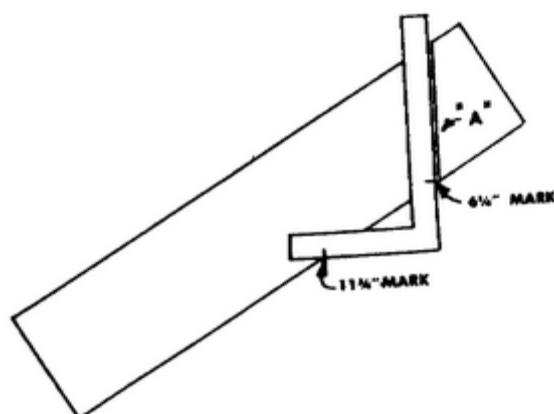


Figure 3-15. Vertical or "plumb" cut for stringer.

vertical cut that will be framed against the platform.

(2) The next step is to mark off the top tread. Using again a rise of 6 1/4 inches but with a run of 2 times 11 3/4 or 23 1/2 inches, lay off the top tread as shown in figure 3-16. By drawing line B 11 3/4 inches long, the top tread has been marked.

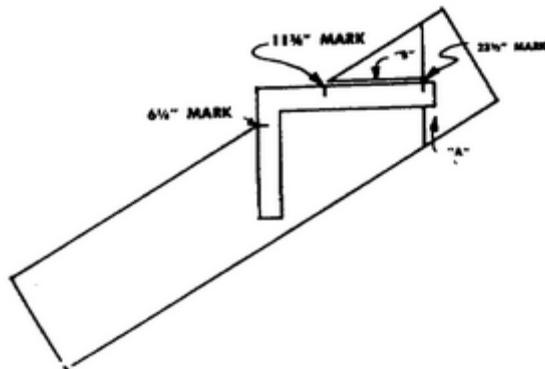


Figure 3-16. First tread cut.

(3) To mark the top riser of the stringer and the second tread from the top, use again a 6 1/4-inch rise and 11 3/4-inch run and mark them in the manner shown in figure 3-17. Line C is the riser and D the tread.

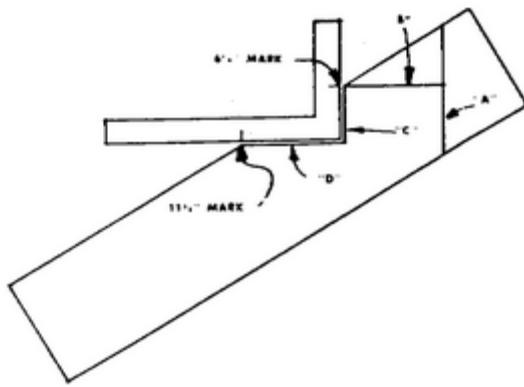


Figure 3-17. Riser and tread layout.

(4) The next tread and riser are marked in exactly the same way as C and D. When this is completed, the only marks still to be laid off are the bottom riser and the horizontal cut at the bottom of the stringer. Figure 3-18 illustrates how the bottom riser is marked. It should be noted again that the bottom riser is **always shorter than the other risers**

by the thickness of a tread - in this case 1 1/2 inches.

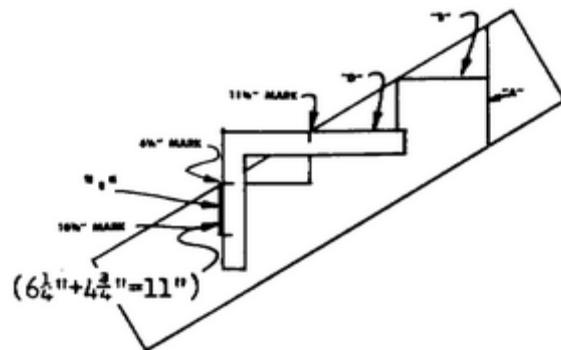


Figure 3-18. Layout of bottom riser.

(5) The final step is to mark the horizontal cut at the lower end of the stringer. It is located by drawing a horizontal line through the lower end of line E. Figure 3-19 shows the placement of the framing square. When this line has been drawn, the layout of the stair stringer is complete. The stringer can then be cut out and used as a pattern for other stringers of the same stairs, either conventional or built-up.

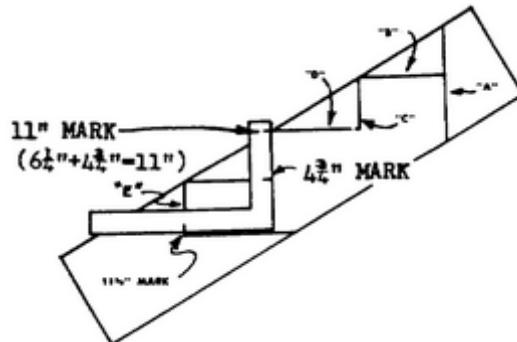


Figure 3-19. Marking the bottom horizontal cut.

c. The triangular blocks cut out in cutting conventional stringers from 2 x 12 or similar stock can be used to make built-up stringers. The blocks are toenailed to a piece of 2 x 4 stock as shown in figure 3-20. The vertical cut (fig. 3-15) and the bottom cut (fig. 3-19) are obtained by using an already cut conventional stringer as a pattern, adding pairs of scabs if necessary to fill out the

vertical (last) or bottom (first) cut. The triangular blocks can also be cut from 2 x 6 or 8-inch stock.

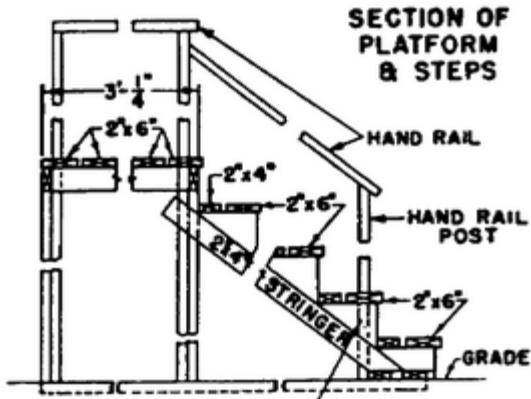


Figure 3-20. Built-up stair stringer.

3-13. ELECTRICAL SYMBOLS

A study of utility installation in TO buildings is beyond the scope of this subcourse. But since the location and type of electrical wiring and fixtures are normally shown on plan views, you should be able to recognize the basic electrical portion of architectural drawings. Some of the most commonly used symbols are shown in figure 3-21.

3-14. FIRE PREVENTION

Since fire is always a danger in TO structures, precautions must be taken to reduce this hazard. It is important to know where to insulate against intense heat and how far wood framing must be placed from stoves, stovepipes, flues, and chimneys, in order to prevent fires.

a. Framing around stovepipes is of major importance to the carpenter in the theater of operations since stoves are the usual method of heating buildings. The pipes are carried out of the building by several methods. Figure 3-22 shows how the pipe is carried through the ridge of the roof. Here the sheathing must be cut to form an opening at least 12 inches larger than the pipe. The stove, where possible, should be set so that the rafters need not be cut. The ceiling joists or tie beams must also be considered. Figure 3-22 also presents a detailed

description of the method of framing a pipe through the ridge. Where a roof jack is not used, the sheathing and other wood should be at least 6 inches from the pipe. If some type of insulation board is available, the wood should be covered with this. Figure 3-23 shows the pipe through the roof when the slope is in one direction. The framing is placed as stated above. In many cases stovepipes are carried to the outside of the building through the side wall. This eliminates flashing and waterproofing around the pipe or roof jack (fig. 3-24). Here the sheathing on the side is cut back 6 inches from the pipe and some type of insulating material is used, if possible.

b. (1) Where stovepipes are carried through the roof, roof jacks are used with flashing attached (figs. 3-22 and 3-23). In most cases these are installed over the roof and nailed. Fibered tar cement is used around the edges and over the nail heads, and the roof jack is soldered to the stovepipe, if practicable. If the roof jack is used on a metal roof, it is soldered to the roof if practicable; otherwise, the tar cement is used around the edge after it has been nailed securely (fig. 3-23). Where no roof jack is used, the hole is covered with a piece of sheet metal which has a hole cut to the size of the stovepipe. The sheet metal is placed over the roofing at the bottom edge, and under it at the top edge. Where a metal roof is used, the flashing is soldered to the roof or fastened by means of tar cement. When the stovepipe does not go through the roof but out through the wall, no flashing is required; only one piece of sheet metal slightly larger than the wall opening, with a hole the size of the pipe is necessary. This is nailed over the opening in the wall (fig. 3-24).

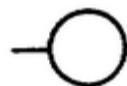
(2) Where a stovepipe goes through the sheet metal, a hole must be cut. The best method is to mark a circle on the metal 1/2 inch larger in diameter than the pipe, then make another circle on the inside with a diameter 2 inches less than the diameter of the first. With a straightedge, draw lines through the center of the circle from the outside. These marks should be from 1/2 to 3/4 inch apart along the outer circumference. Cut out the center circle, then cut to the outside

1 LIGHTING OUTLETS

a CEILING



b WALL



2 SWITCHES

a SINGLE POLE

S

KEY-OPERATED
SWITCH

SK

b DOUBLE POLE

S2

g DOOR SWITCH

SD

c THREE-WAY

S3

h TIME SWITCH

ST

d SWITCH AND PILOT
LAMP

SP

i CIRCUIT
BREAKER
SWITCH

SCB

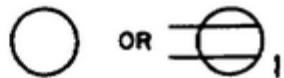
e CEILING PULL
SWITCH



Figure 3-21. Electrical symbols.

3 RECEPTACLE OUTLETS

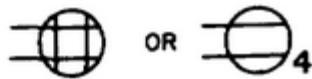
a SINGLE OUTLET



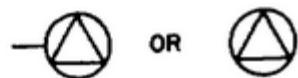
b DUPLEX OUTLET



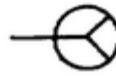
c QUADRUPLEX OUTLET



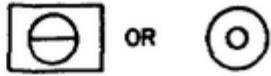
d SPECIAL PURPOSE OUTLET



e 20-AMP, 250-VOLT OUTLET



f SINGLE FLOOR OUTLET
(BOX AROUND ANY OF ABOVE
(INDICATES FLOOR OUTLET OF
SAME TYPE)



4 MISCELLANEOUS

a WIRING CONCEALED IN
CEILING OR WALL



b WIRING CONCEALED IN FLOOR



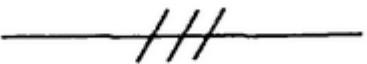
c EXPOSED BRANCH CIRCUIT



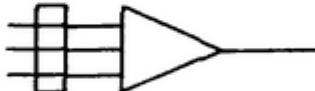
d BRANCH CIRCUIT HOME RUN TO
PANEL BOARD (NO. OF ARROWS
EQUALS NO. OF CIRCUITS.
DESIGNATION IDENTIFIES
DESTINATION AT PANEL)



e THREE OR MORE WIRES (NO. OF
CROSS LINES EQUALS NO. OF
CONDUCTORS TWO CONDUCTORS
INDICATED IF NOT OTHERWISE
NOTED)



f INCOMING SERVICE LINES



g CIRCUIT
BREAKER-AIR

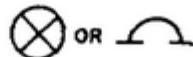


Figure 3-21. Electrical symbols (continued).

of the circle along the lines drawn. After the lines have been cut, bend the metal strips outward at a 45° angle and force the pipe through the hole to the desired position. Very little water will leak around this joint (fig. 3-24).

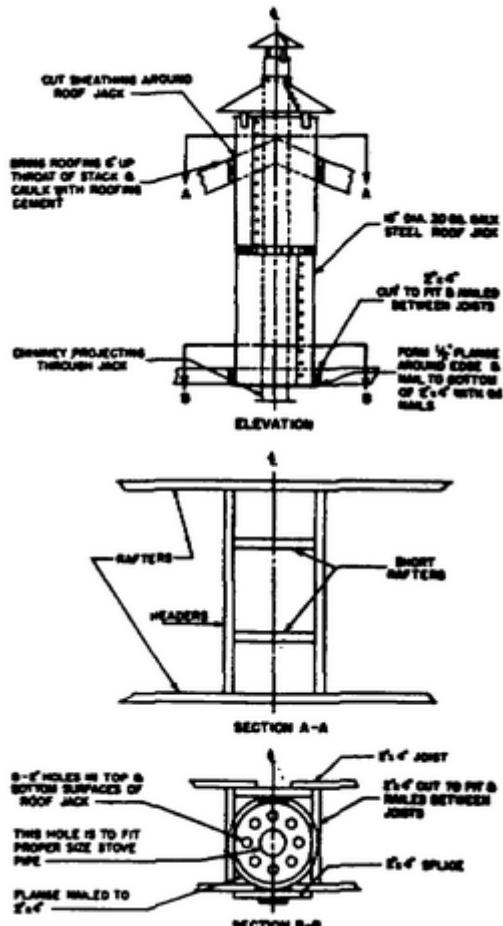


Figure 3-22. Smoke pipe through roof ridge.

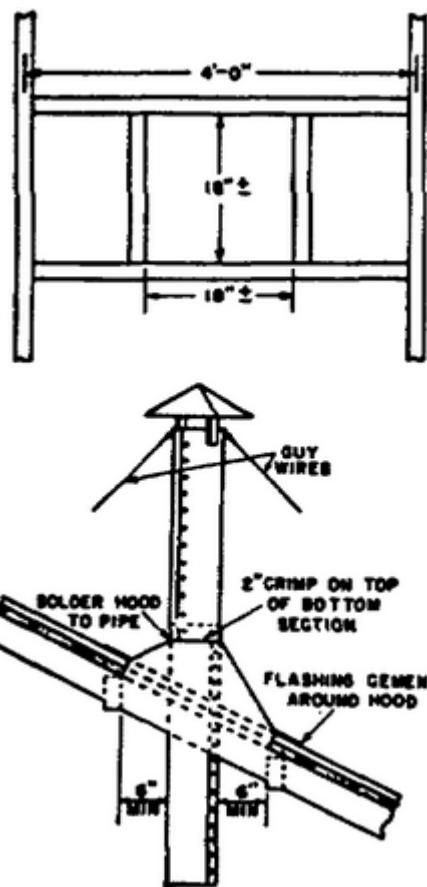


Figure 3-23. Smoke pipe through roof slope.

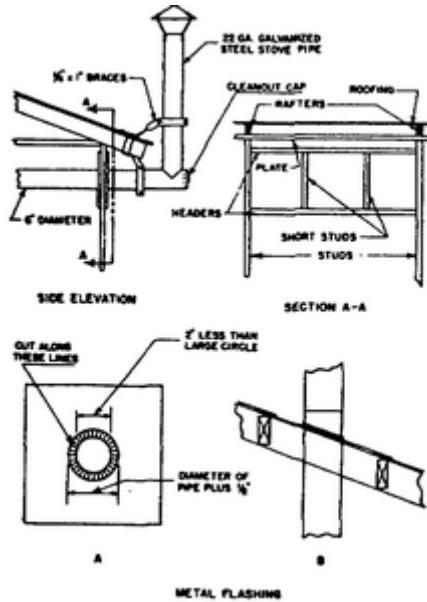


Figure 3-24. Smoke pipe through side wall.

SELF TEST

Note: The following exercises comprise a self test. The figures following each question refer to a paragraph containing information related to the question. Write your answers in the space provided below each question. When you have finished answering all the questions for this lesson compare your answer with those given for this lesson in the back of this booklet. Review the lesson as necessary. Do not send in your solutions to these review exercises.

1. Plywood is used frequently as a construction material in framed structures. What advantages are there in using plywood instead of solid wood? (Para 3-1b)

2. In slatted sheathing, what is meant by "one-in-three" spacing, and when is it used? (Para 3-3c)

3. What two types of roofing are used by the Army in TO construction? (Para 3-4)

4. In the design of a gable roof for a small storage building, each rafter will have a horizontal run of 10 feet. If you use corrugated sheet metal roofing, what is the least total rise each rafter must have? (Para 3-5a)

5. How many rolls of 40-pound prepared roll roofing will you need to cover a gable roof on a building 60 feet long with rafters having a line length of 11 feet 4 inches and a 2-foot overhang? (Para 3-5b)

6. Corrugated sheet metal roofing cannot be used for slopes less than 4 inches per foot. Prepared roll roofing cannot be used for slopes less than 1 inch per foot. How can you cover a flat roof? (Para 3-5b)

7. A valley is formed where two roofs come together at an angle. What are the two most common methods used in TO construction, to waterproof this valley? (Para 3-6)

8. Sheathing is being applied to the rafters of a building on which 40-pound prepared roofing is to be installed. The rafters do not overhang. Describe the placement of the first piece of sheathing. (Para 3-8b)

9. When corrugated sheet metal is used as the roof covering, what measure can be taken to provide added protection to the building walls? (Para 3-8c)

10. Why is it that less framing lumber is required in a structure when the sheathing is placed vertically than when it is placed horizontally? (Para 3-9b)

11. Three common types of siding are: beveled siding, drop siding, and shiplap. What disadvantage is there in bevel siding in comparison to the others? (Para 3-9c)

12. Why is it inadvisable to install asphaltic felt or tar paper behind corrugated sheet iron which is being installed as a wall covering? (Para 3-9d)

13. What is the main difference between the construction of an interior door fame and an exterior door frame? (Para 3-10e)

14. T-strap hinges are used to hang batten doors in TO construction. Explain the placement of these hinges. (Para 3-10d)

15. What is the purpose of wainscoting and where is it installed? (Para 3-10h)

16. For a finish flooring, you plan to use 1 x 4 tongue-and-groove lumber over a diagonal subfloor. In what direction should these boards run? (Para 3-10i)

17. Determine the rise and tread for the outside stairs of a TO building with a total rise of 38 inches. Check it by the rules given. (Para 3-11b)

18. In constructing steps for a barracks, plans call for the use of 2 x 12 lumber for treads. The stair stringers have four 7-inch risers and a bottom riser. What height cut (in inches) should be made for the bottom riser? (Para 3-12b, (4))

19. When roof jacks are not available a piece of sheet metal can be used to carry a stove pipe through the roof of TO structures. What is the minimum distance in inches that sheathing and other wood may be to the pipe? (Para 3-14a)

20. When a stovepipe goes out through a wall instead of the roof, what is required for fire prevention at that type of installation? (Para 3-14b(1))

LESSON 4

MATERIALS ESTIMATING

CREDIT HOURS	2
TEXT ASSIGNMENT	Attached memorandum.
MATERIALS REQUIRED	None.
SUGGESTIONS	Review the preceding lessons, with particular attention to construction drawings; nomenclature; and standards for materials, nominal dimensions, and nail sizes.

LESSON OBJECTIVES

Upon completion of this lesson on materials estimating you should be able to accomplish the following in the indicated topic areas:

1. Importance of estimating. Relate the importance of estimating to the overall planning of a construction project.

2. Qualifications and training of estimators. Outline the qualifications a good materials estimator should possess and the training and experience necessary to develop these skills.

3. Prepare a bill of materials. Prepare a bill of materials following the five steps outlined in this lesson.

ATTACHED MEMORANDUM

4-1. TOTAL ESTIMATING

a. Importance of estimating. One of the most important steps in planning a construction project is estimating. It should be considered the first approach in scheduling cost of time and materials. In military construction carelessly made estimates may lead to failure to meet completion dates; may cause uneconomical use of men, materials, and equipment; and may seriously jeopardize a tactical or strategic situation. The military construction manager must have competent estimators in his organization as well as being a good estimator himself.

b. Steps in overall estimating.

(1) An estimator's first task is to study the plans and specifications from which he computes

the main portion of the estimate. He should compare the specifications with the plans to insure proper application of the specifications. After this, he should visit the work site to become thoroughly familiar with local conditions.

(2) The next step the estimator must do is prepare a checklist of tasks that have to be performed to complete the project. Experience enables the estimator to determine the sequence of the tasks. However, the less experienced estimator can gain some insight into this process by examining the plans and specifications.

(3) The third step in estimating is the preparation of a bill of materials. Information

for preparing the bill of materials is obtained from drawings and specifications.

(4) The fourth step is the preparation of a labor and equipment estimate. This is a listing by type, amount of time, and number of personnel required to complete each task of the project.

(5) The final step is to summarize the amount of materials, equipment, and labor required for each task on the estimate or checklist. The estimator should insure at this point that nothing is omitted or duplicated.

c. **Lesson coverage.** In this lesson, we will concentrate on and fully discuss step three above, preparation of a bill of materials.

4-2. QUALIFICATIONS AND TRAINING OF A MATERIALS ESTIMATOR

a. **Qualifications of a materials estimator.** A materials estimator is one who prepares materials estimates. He should possess the following qualifications:

- (1) Ability to read plans accurately.
- (2) A good knowledge of arithmetic.
- (3) Ability to compute accurately.
- (4) Ability to visualize both the planning steps and the finished product of a construction project.
- (5) A knowledge of materials.
- (6) Ability to use pertinent Department of the Army publications.

b. **Training in materials estimating.** A man may be taught methods, calculations involved, items to include, and errors to avoid in materials estimating. However, he cannot be taught the indispensable factors of experience and judgment. These he must acquire over a period of time.

4-3. MATERIAL ESTIMATES

a. **Sources of information.** Plans and specifications for bridges, building, and other vertical structures normally contain bills of materials. When they do, the materials estimator should check the bill against the drawings and specifications for any discrepancies. If alterations or modifications of the

plans are necessary, which is frequently the case for facilities of the Army Facilities Components System (AFCS), the materials estimator will have to make the required additions and deletions to the accompanying bills.

b. **Omission of bill of materials.** When a bill of materials is not provided with the drawings and specifications for a construction project, the materials estimator must prepare one from the drawings and specifications.

4-4. PREPARING A BILL OF MATERIALS

a. **Essential elements.** The methods discussed in this lesson are representative only. The materials estimator has latitude in preparing his own system. However, listed below are five essential elements of whatever system he uses.

- (1) Take-off list.
- (2) Consolidation.
- (3) Waste allowance.
- (4) Nail requirements.
- (5) Grouping and arranging.

b. **Explanation.** The following paragraphs illustrate and explain a recommended method of preparing a bill of materials incorporating these five elements. The additional elements of thoroughness, accuracy, and neatness are stressed here because they are vital to successful material estimating.

4-5. TAKE-OFF LIST

a. **Definition.** A take-off list is a descriptive and individual listing of each part in a structure. It gives the materials estimator the opportunity to determine firsthand the kind and quantities of materials needed. The method discussed below for preparing a materials takeoff is reliable and thorough. It incorporates the principle that the materials estimator, when preparing the take-off list from a drawing, will work in a systematic manner.

b. **Method.** In preparing a takeoff list follow the rule "keep it separate." Whenever a part (item) is taken off a drawing or

specification, it is listed **separately**, described individually, and specifically allocated.

(1) Parts are not combined unless **size and nomenclature are identical**. A structure may have 20 posts (all same nomenclature) but any one or all of these posts would be listed and described individually if any difference in size existed. Also, a part having the identical size of any other differently named part would be separately itemized and described.

(2) The second step in preparing a take-off list is listing and describing the part in detail. For example, the number of pieces, nominal size, and length in place of wooden pieces would be listed. For parts other than wood, the listing consists of full description by nomenclature, size and/or quantity.

(3) The third phase of a take-off list is indicating the standard lengths of lumber to use for each wooden part listed and described. This requires that the materials estimator know the different sizes of lumber available at the depot and which sizes will produce the most parts with the least waste. This phase includes determining the number of pieces per part each standard length will produce and the number of standard lengths required for the total number of pieces per part.

c. **Form.** In general the take-off list should contain these important columns: (1) item, (2) part, (3) number of pieces, (4) nominal size, (5) length in place, (6) standard length, (7) number of pieces per standard length, and (8) number of standard lengths.

4-6. DEVELOPMENT OF TAKE-OFF LIST

a. Development of a take-off list begins with examination of the plans and follows the method described in paragraph 4-5b, above. For example, let us develop the first five columns of a take-off list for a scrub table shown in figure 4-1.

(1) Starting at the bottom, from the front and end views, note (as visualized through the detail) that the cable has two side rails (bottom) each made up of 2 x 4's, 4' - 6" long. Enter this as item 1

under column 1 and record the remaining information under columns 2 through 5, as follows:

(1) Item	(2) Part	(3) Number of pieces	(4) Nominal size	(5) Length in place
1	side rail (bottom)	2	2 x 4	4'-6"

(2) The second item, from the same front and end view, is the end rail (bottom). Two pieces are also required, each 2 x 4. The length in place, 3' - 0", is located in the end view. Incorporating this information, as above, the following listing would result;

(1) Item	(2) Part	(3) Number of pieces	(4) Nominal size	(5) Length in place
2	end rail (bottom)	2	2 x 4	3'-0"

(3) Working systematically and in a logical sequence, take-off item three (3). Note that it is a pair of top side rails, one rail for each side of the table. Dimensions are 2 x 4 - 4' - 6". The next item (4) labeled for take-off is the top end rail. Two of them are required, one for each end, in nominal size of 2 x 4. The length in place, shown in the side view, is 3' - 0". Here are the entries for items 3 and 4.

(1) Item	(2) Part	(3) Number of pieces	(4) Nominal size	(5) Length in place
3	side rail (top)	2	2 x 4	4'-6"
4	end rail (top)	2	2 x 4	3'-0"

(4) Next, note item 5, the intermediate rail. Like item 4, it is a 2 x 4 (3' - 0" long) member and provides support to the table top. Four legs (item 6) in nominal size of 2 x 4 with length in place of 3' - 0" complete the items on the lower part of the table. Take-off items 5 and 6 are listed as follows:

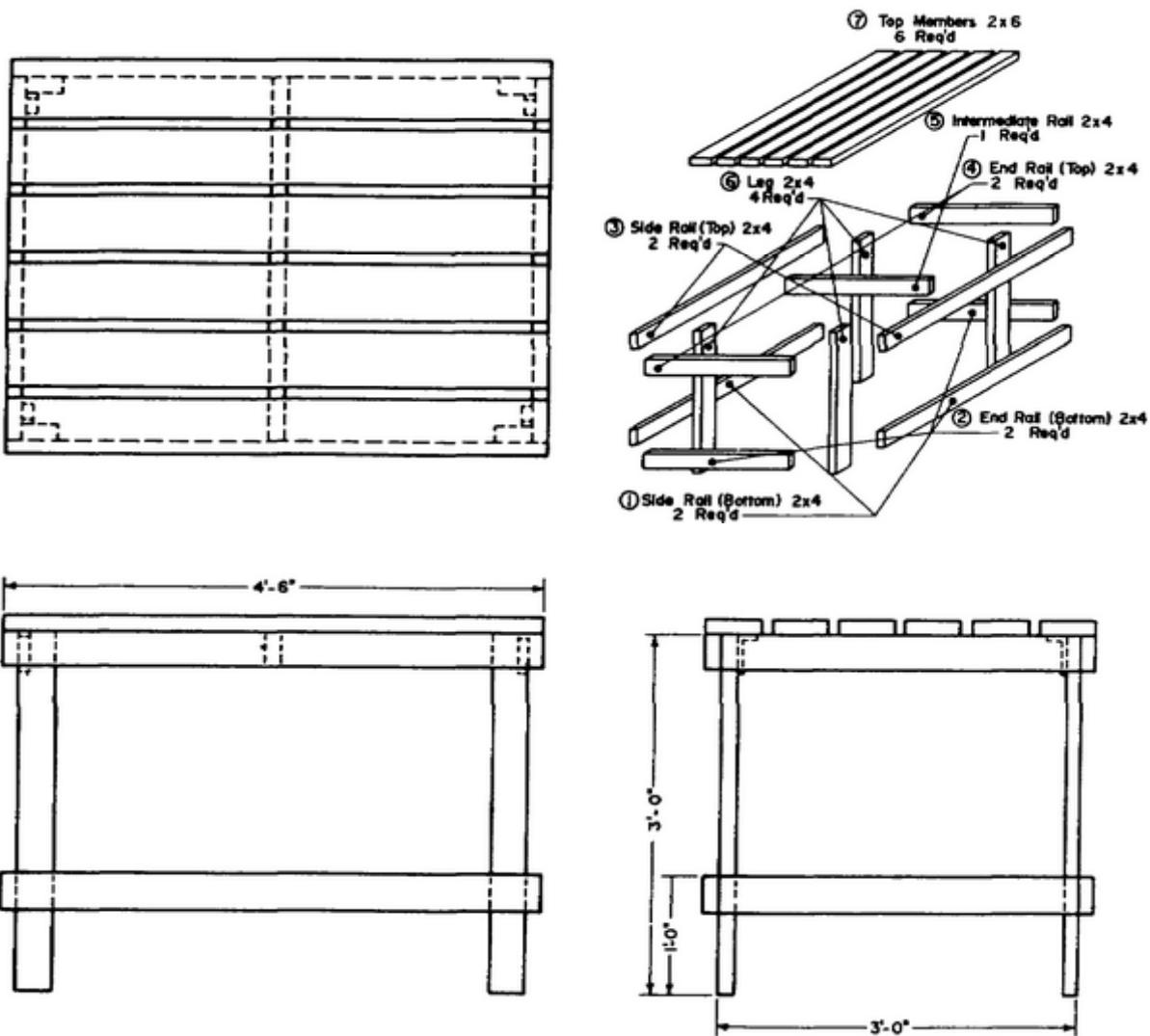


Figure 4-1. Scrub table detail.

(1) Item	(2) Part	(3) Number of pieces	(4) Nominal size	(5) Length in place
5	intermediate rail	1	2 x 4	3'-0"
6	legs	4	2 x 4	3'-0"

(5) The final item to takeoff, item 7, is located in the top view of figure 4-1. It is the table top, composed of six members with dimensions of 2 x 6, 4' - 6" long. Here is the entry for top members:

(1) Item	(2) Part	(3) Number of pieces	(4) Nominal size	(5) Length in place
7	top members	6	2 x 6	4'-6"

b. Development of the last three columns (6 through 8) of the takeoff list requires some calculations.

(1) For columns 6 and 7, it is necessary to determine the standard length of material from which the items (parts) can be cut and how many can be cut from the length

selected. The shortest standard length (they range from 8 feet to 20 feet in 2-foot increments, paragraph 1-17a, lesson 1) which supplies the most pieces with the least waste is normally chosen, i.e., usually several short pieces (up to 6 feet) can be cut from one standard length whereas pieces measuring more than 6 feet normally require the entire standard length. The selected standard length is entered in column 6. For convenience all measurements should be converted to inches. Footage is converted into inches prior to actual computation. i.e., 8 feet = 96 inches (8 x 12), 10 feet = 120 inches (10 x 12), and so on. The entry for column 7 (number per standard length) is developed by dividing the standard length in column 6 by the length in place in column 5.

(2) The number of standard lengths for column 8, is then developed by dividing column 3 (number of pieces) by column 7.

c. Continuing the example of the scrub table (a above) and following the method just described columns 6, 7, and 8, let us proceed to finalize the takeoff list.

(1) Complete item 1, listed in a(1), above. Note that two pieces, each 4' - 6" long, are required. To develop columns 6 and 7 which relate to each other, try a 10-foot length.

Converting to inches:

$$10' - 0" = 10 \times 12 = 120 \text{ inches}$$

$$4' - 6" = (4 \times 12) + 6 = 48 +$$

Then: $6 = 54 \text{ inches}$

$$\frac{120}{54} = 54 \sqrt[2]{120}$$

$$\frac{108}{12} \quad \text{(waste)}$$

= 2 pieces w/12 inches waste

Trying a 12-foot standard length:

$$12' - 0" = 12 \times 12 = 144 \text{ inches}$$

$$4' - 6" = (4 \times 12) + 6 = 48 +$$

$$6 = 54 \text{ inches}$$

Then:

$$\frac{144}{54} = 54 \sqrt[2]{144}$$

$$\frac{108}{36} \quad \text{(waste)}$$

= 2 lengths w/36 inches waste

It is apparent the 10-foot standard length is more economical and should be selected for column 6. Column 7, as a result of this calculation, would list 2 as the number of pieces which can be cut from the length selected. Developing column 8 (number of standard lengths), divide the number of pieces listed in column 3 by column 7.

$$\frac{2}{2} = 1$$

Thus columns 6, 7, and 8 for item 1 would be:

(1) Item	(2) Part	(3) Number of pieces	(5) Length in inches	(6) Standard length	(7) Number of pieces per standard length	(8) Number of standard lengths
1	side rail (bottom)	2	4'-6"	10'-0"	2	1

Note: In this example, column 4 is omitted since it is not used in the calculations.

(2) Continuing with item 2 (a(2), above), observe that the item requires two pieces, each 3' - 0" long. In selecting the standard length (column 6) and the number per standard length (column 7), calculate on the closest standard length by trying an 8-foot versus a 10-foot length.

Converting to inches:

$$8' - 0" = 8 \times 12 = 96 \text{ inches}$$

$$3' - 0" = 3 \times 12 = 36 \text{ inches}$$

Then:

$$\frac{96}{36} = 36 \sqrt[2]{96}$$

$$\frac{72}{24} \quad \text{(waste)}$$

= 2 pieces w/24 inches waste

Similarly for:

$$10' - 0'' = 10 \times 12 = 120 \text{ inches}$$

$$3' - 0'' = 3 \times 12 = 36 \text{ inches}$$

Then:

$$\frac{120}{36} = 3 \frac{3}{12}$$

$$\frac{108}{12} \quad (\text{waste})$$

$$= 3 \text{ pieces w/12 inches waste}$$

Note: If a 10-foot length was used there would be 48 inches waste, the unnecessary third length (36 inches) plus 12 inches waste.

Thus for column 6, the 8-foot standard length is chosen as it will supply the two required number of pieces (column 3) with the least waste. Again, for column 8, divide the number of pieces (column 3) by number per standard length (column 7).

$$\frac{2}{2} = 1$$

Hence, the developed entries for columns 6, 7, and 8 for item 2 would be:

(1) Item	(2) Part	(3) Number of pieces	(4) Length in piece	(5) Standard length	(6) Number of pieces per standard length	(8) Number of standard lengths
2	end rail (bottom)	2	3'-0"	8'-0"	2	1

Note: In this example, column 4 is omitted since it is not used in the calculations.

(2) Continuing with item 2 (a(2), above), observe that the item requires two pieces, each 3' - 0" long. In selecting the standard length (column 6) and the number per standard length (column 7), calculate on the closest standard length by trying an 8-foot versus a 10-foot length.

(3) Note that items 3 and 4 have the same size and number of pieces requirement as items 1 and 2, hence, no additional computations are required. Thus the listings of items for 3 and 4 (for columns 6, 7, and 8) are the same as for items 1 and 2, respectively.

(1) Item	(2) Part	(3) Number of pieces	(4) Length in piece	(5) Standard length	(6) Number of pieces per standard length	(8) Number of standard lengths
3	side rail (top)	2	4'-6"	10'-0"	2	1
4	end rail (top)	2	3'-0"	8'-0"	2	1

(4) For item 5, use a short standard length of 8 feet since, in this instance, only one piece is required. Item 6 is similar to item 2 and will be listed accordingly; only the number standard lengths in column 8 will be different:

$$\frac{4}{2} = 2$$

The entries for columns items 5 and 6 are as follows:

(1) Item	(2) Part	(3) Number of pieces	(4) Length in piece	(5) Standard length	(6) Number of pieces per standard length	(8) Number of standard lengths
5	inter- mediate rail	1	3'-0"	8'-0"	1	1
6	leg	4	3'-0"	8'-0"	2	2

(5) Since item 7 is 4' - 6" long (same as items 1 and 3) select the 10-foot standard length as it will supply two lengths with least waste. Then to develop column 8 (number of standard lengths) compute:

$$\frac{6 \text{ (colm 3)}}{2 \text{ (colm 7)}} = 3$$

Developed columns for item 7 follow:

(1) Item	(2) Part	(3) Number of pieces	(4) Length in piece	(5) Standard length	(6) Number of pieces per standard length	(8) Number of standard lengths
7	top members	6	4'-6"	10'-0"	2	3

d. The completed take-off list for the scrub table is shown in figure 4-2.

(1) Item	(2) Part	(3) Number of Pieces	(4) Nominal Size	(5) Length in Place	(6) Standard Length	(7) Number of Pieces per Standard Length	(8) Number of Standard Lengths
1	side rail (bottom)	2	2 x 4	4'-6"	10'-0"	2	1
2	end rail (bottom)	2	2 x 4	3'-0"	8'-0"	2	1
3	side rail (top)	2	2 x 4	4'-6"	10'-0"	2	1
4	end rail (top)	2	2 x 4	3'-0"	8'-0"	2	1
5	inter- mediate rail	1	2 x 4	3'-0"	8'-0"	1	1
6	legs	4	2 x 4	3'-0"	8'-0"	2	2
7	top members	6	2 x 6	4'-6"	10'-0"	2	3

Figure 4-2. Completed take-off list for scrub table.

4-7. CONSOLIDATION

a. Having completed the take-off list (fig. 4-2), we are ready to consider the development of the consolidation element for a bill of materials (par. 4-4a(2), above). Consolidation on a bill of materials is the process of combining into one listing all identical items, regardless of nomenclature. This process turns the detailed and lengthy take-off list into a concise and easily read list of materials. The method for developing the information on a consolidated list of materials and the takeoff list (pars 4-5 and 4-6, above) is identical with the exception of columns 2 and 3.

- (1) Column 2 (part) lists the name of the part or parts consolidated into one entry.
- (2) Column 3 (number of pieces) lists the total number of pieces required for all the parts listed in column 2.
- b. Continuing with the example of the scrub table, consider consolidation of the take-off list.

(1) Note that items 1 and 3 are identical. Each is made up of 2 x 4's, 4'-6" long. Enter these as item 1, column 1, and record the remaining information under columns 2 through 8, as follows:

(1) Item	(2) Part	(3) Number of pieces	(4) Nominal size	(5) Length in place	(6) Standard length	(7) Number of pieces per standard length	(8) Number of standard lengths
1	side rail (top and bottom)	4	2 x 4	4'-6"	10'-0"	2	2

(2) Further note that items 2, 4, 5, and 6 are identical, each 2 x 4, 3' - 0" long. Consolidating these items requires a recalculation of column 6 (standard length). Thus, this information would result in the following entry:

(1) Item	(2) Part	(3) Number of pieces	(4) Nominal size	(5) Length in place	(6) Standard length	(7) Number of pieces per standard length	(8) Number of standard lengths
2	end rails (bottom and top) intermediate rail, legs	9	2 x 4	3'-0"	*10'-0"	3	3

*Select the 10-foot length now (par. 4-6c(2), above). For nine pieces, it is more economical.

(3) Note that item 7 is not identical with any other item. Thus, it would be listed as shown below without consolidation:

(1) Item	(2) Part	(3) Number of pieces	(4) Nominal size	(5) Length in place	(6) Standard length	(7) Number of pieces per standard length	(8) Number of standard lengths
3	top members	6	2 x 6	4'-6"	10'-0"	2	3

c. Figure 4-3 shows the completed consolidated list for the scrub table.

d. Demonstrating another example of consolidation, let us develop the number of board feet (BF) par. 1-18 and table 1-3, lesson 1) in the standard lengths required for the scrub table.

(1) Noting that items 1 and 2 are identical (fig. 4-3) by size and length of pieces, consolidate the number of standard lengths (column 8)(2 + 3 = 5). Using table 1-3, convert to BF:

(2 x 4, 10'-0" long = 6 $\frac{2}{3}$; BF).

$$\text{Computing: } 6\frac{2}{3} \times 5 = \frac{20}{3} \times 5 = \frac{100}{3} \quad \text{or} \quad 33 \text{ BF}$$

(2) Since item 3 has no identical part, one 2 x 6, 10' - 0" long = 10 BF x 3 standard lengths (column 8) or 30 BF

(3) Therefore, each scrub table contains a total of 63 BF (33 + 30).

(1) Item	(2) Part	(3) Number of Pieces	(4) Nominal Size	(5) Length in Place	(6) Standard Length	(7) Number of Pieces per Standard Length	(8) Number of Standard Lengths
1	side rails (top and bottom)	4	2 x 4	4'-6"	10'-0"	2	2
2	end rails, inter- mediate rail, and legs	9	2 x 4	3'-0"	10'-0"	3	3
3	top members	6	2 x 6	4'-6"	10'-0"	2	3

Figure 4-3. Consolidated list for scrub table.

4-8. WASTE ALLOWANCE

Waste allowance, the third essential element (par. 4-4a(3)) of a bill of materials, is important because during construction a certain amount of material is wasted due to cutting, fitting, and handling. For example, lumber comes in standard lengths which seldom can be used without cutting and fitting. Sometimes the piece of lumber cut off is used, but more often it goes into the scrap heap. Another example is mortar sand which is normally stored at the job site. The sand on the bottom of the pile cannot be picked up without some earth getting in it. This generally makes the sand unusable and therefore wasted. Likewise, some electrical items, wire outlets, toggle switches, insulators, and so forth, are wasted due to malfunctioning, wrong size, damage, and so on. Thus, waste allowance must be included in a bill of materials to cover unavoidable losses. Table 4-1 lists the different allowances for waste. Note that the allowance percentages are based on the function of the item. When developing waste allowances, multiply the total quantity of any one particular part

TABLE 4-1. Allowances for Waste

Item	Allowance
Dimension lumber — 2 inches or more thick	10%
Sheathing and flooring — less than 2 inches thick	20%
Matched boards — 3 inches or more wide	33%
Matched boards — less than 3 inches wide	50%
Common wire nails	20%
Other construction material	5% - 10%

(standard lengths, units, rolls, concrete mixtures, and so forth) by the applicable waste allowance (table 4-1). Then include the result on the final bill of materials. (In computing waste, count any fraction from .5 up as a whole number; drop anything less.) Ordinarily no waste allowance would be taken on items such as scrub table parts. However, if 100 such tables were to be built, 500 pieces of 2 x 4's, 10' - 0" long and 300 pieces of 2 x 6's, 10' - 0" long would be required (results of items 1 and 2 combined and item 3 (fig. 4-3) multiplied by 100). An allowance of 10

percent for waste is made on each item, so 550 pieces and 330 pieces would be listed respectively in the bill of materials.

4-9. NAIL REQUIREMENTS

Nail requirements (par. 4-4a(4)) are expressed in pounds of nails. The quantity of nails required can be determined by counting the number of joints in simple structures, by using the formulas for approximate quantities or by using table 1-3 in lesson 1. When the quantity of nails is determined by counting joints, allow two nails per joint for material up to 8 inches wide and three per joint for wider material.

a. Nail requirements can also be estimated by use of the following formulas:

$$\begin{aligned} \text{(1) For framing members (dimension lumber), pounds of nails per MBF} &= \\ \text{Size of nail in pennies} \times 10 &\quad \text{or pounds of} \\ &\quad \frac{6}{nails \text{ per MBF}} = 1.67d. \end{aligned}$$

$$\begin{aligned} \text{(2) For sheathing and flooring, pounds} \\ \text{of nails per MBF} &= \\ \text{Size of nail in pennies} \times 10 &\quad \text{or pounds of} \\ &\quad \frac{4}{nails \text{ per MBF}} = 2.5d. \end{aligned}$$

b. The nail size should be at least 1.5 to 2 times the thickness of the wood it is intended to hold if it is driven across the grain of the second piece of wood and at least 3 times the thickness of the wood it is intended to hold if it is driven with the grain of the second piece of wood. Table 1-3 gives some recommended nail sizes and the quantities required for various elements of frame structures.

c. For example, let us determine the size and quantity of nails required to finish 100 scrub tables.

The greatest thickness of wood the nail is intended to hold is 1 1/2 inches. The nails will be driven across the grain of the second piece of wood. Nail lengths should be at least 1.5 or 2 times 1 1/2 inches. Two times the thickness of a 2 x 4 is 3. Select a 3-inch length, or 10-penny common nail. Since this is a simple structure, the number of nails

required will be determined by counting the joints. Referring to figure 4-1, there are 30 joints. Only two nails are required per joint because the maximum width is less than 8 inches. Thirty joints per table x 2 nails per joint = 60 nails/table. The job requirement is for 100 tables,

$$100 \text{ tables} \times 60 \text{ nails per table} = 6000 \text{ nails}$$

From table 4-1, the allowance for waste for common wire nails is 20%.

$$6000 \times 1.20 = 7,200 \text{ nails}$$

The number of 10d per pound from figure 1-15 or table 1-3 is 74 nails per pound.

$$\frac{7,200 \text{ nails}}{74 \text{ nails/pound}} = 97.3 \text{ pounds, say } 97 \text{ pounds of 10d common nails}$$

d. In comparison, determine the quantity of nails to construct the 100 scrub tables required by using the formula for framing members:

$$\begin{aligned} \text{pounds of nails per MBF} &= 1.67d \\ &= 1.67 \times 10 = \\ &= 16.7 \end{aligned}$$

Referring to paragraph 4-7d(3), there are 63 BF per scrub table or 6,300 BF per 100 scrub tables or 6.3 MBF per 100 scrub tables.

Thus the number of pounds of nails required:

$$16.7 \text{ pounds of nails per MBF} \times 6.3 \text{ MBF} = 105.21 \text{ pounds of nails say } 105 \text{ pounds of 10d common nails.}$$

For this case, the formula gives a value that is 8.25% greater than the exact amount plus the standard allowance for waste

$$\frac{105 - 97}{97} \times 100 = 8.25\%$$

e. The following example on the use of table 1-3 will illustrate its usefulness: What size, kind, and quantity of nails are required to lay 1 x 4 flooring for a room 50 x 100, joists spaced 16 inches on centers?

Referring to table 1-3 look in the first column headed "Sizes and Kinds of Materials" and find "Flooring 1 x 4." Read horizontally across to the second column headed "sizes" and find the size and kind as **8d floor brads**.

Continue horizontally across to the column headed 16" under "Pounds per MBF on center as follows" and find the quantity 26 pounds.

BF in flooring 1 inch thick = $50 \times 100 = 5,000$ = 5 MBF

26 pounds of nails x **5 MBF = 130 pounds**

Thus the required size, kind, and quantity is **130 pounds of 8 floor brads**.

f. The following will also be found convenient in estimating the quantity of nails required for building frame structures:

- (1) For 1,000 shingles, allow 5 lb 4-penny nails or 3 1/2 lb 3-penny.
- (2) For 1,000 laths, 7 lb 3-penny fine, or for 100 sq yd of lathing, 10 lb 3-penny fine.
- (3) For 1,000 sq ft of beveled siding, 18 lb 6-penny.
- (4) For 1,000 sq ft of sheathing, 20 lb 8-penny or 25 lb 10-penny.
- (5) For 1,000 sq ft of flooring, 30 lb 8-penny or 40 lb 10-penny.
- (6) For 1,000 sq ft of studding, 15 lb 10-penny and 5 lb 20-penny.
- (7) For 1,000 sq ft of 1 by 2 1/2 in. furring, 12 in. centers, 9 lb 8-penny or 14 lb 10-penny.

(8) For 1,000 sq ft of 1 by 2 1/2 in. furring, 16 in. centers, 7 lb 8-penny or 10 lb 10-penny.

4-10. GROUPING AND ARRANGING

The last and final element in the preparation of a bill of materials is grouping and arranging (par. 4-4a(5)). It results in a completed bill of materials which facilitates requisitioning.

a. Items are grouped and arranged by sections. Codes applicable to frame structures are as follows:

Code number	Description
01 - 02	Frame and Roof
03	Cladding — Doors and Windows
04	Interior Liner
05	Floor
06	General Interior Construction
07	Plumbing
08	Heating and Ventilation
09	Interior Electric Wiring
10	Interior Fire Protection

These major groupings are then subgrouped according to common items required for the specific work assignment, lumber, nails, hardware, and so forth. Items are arranged within each subgroup by name and size and numbered consecutively. This arrangement may be developed from the consolidated listing.

b. Figure 4-4 shows a finalized bill of materials and illustrates grouping and arranging.

ITEM NO.	SECT NO.	ITEM	UNIT	QUANTITIES REQUIRED				ITEM NO.	ITEM	UNIT	QUANTITIES REQUIRED	
				WALL PANELS	Ceil. ROOF	DOORS	TRUSS					
01-02) FRAME AND ROOF												
1		Lumber 2x6-8 ft	PCS	60	4	4	120	38	1	FLOOR Cement	SC	.75
2		2x6-10 ft	PCS	40	4	4	38	38		HEATING AND VENTILATION Reactor		
3		2x6-14 ft	PCS	20	2	2	38	1		Convection Coal-oil 55-gal Drum	SC	2
4		2x6-12 ft	PCS	40	4	4	38	1		Miscellaneous		
		Nails								Split Roof Insulator #1	SC	.14
		10# Common	LB	6	.6	.6	1.2	2		Nails 6d Common	SC	.25
		16# Common	LB	8	.8	.8	1.6	4		1/2" No. 8 Sheet Metal	SC	.60
										Flat Steel Sheet 28 ga., 30"x120"	SC	.82
										Flat Steel Sheet 20 ga., 48"x96"	SC	.82
										Bimetallic Plastic Cement	SC	1.0
03) CLADDING												
1		Lumber No 2 Lathwood 1x3-15 ft	SC	40	.44	.44	.2	7		INTERIOR ELECTRIC WIRING		
2		1x3-9 ft	PCS	60	2	2				Wire Solid No 14	FT	
3		1x3-14 ft	PCS	340	40	40	12	520	1	Pittings and Miscellaneous Materials		
4		1x6-8 ft	PCS	8						Ground Clamp 1"	SC	1
5		1x6-12 ft	PCS	20	2	2	57	19		Flexible Conduit 3/8"	SC	
6		1x6-16 ft	PCS	4						Cable Connector 6-7	SC	
7		1x6-8 ft	PCS	4						Split Roof Insulator #1	SC	
8		1x6-10 ft	PCS	20	2	2	4			Lamp Baseplate Keyhole	SC	
9		Nails								Porcelain Tube 3/8"x6"	SC	
10		30# Common	LB	4	.4	.4	.4	6		Lumber 2x2-16 ft	SC	
11		8D Common	LB	40	.4	.4	5.6	60		Lumber 2x4-16 ft	SC	
12		7/8" Roofing	LB	5	.5	.5	.4	12		Nails 6d Common	SC	
13		No 9 Double Point Tack	LB	4	.4	.4				Machinist Belt 5/8"x16"	SC	
		Miscellaneous								1 1/4" Roundhead Wood Screws	SC	.13
14		Building Paper 15 lb., 36"x100' wide	SC	40	.4	.4	.4			Washer Iron 5/8"x1 3/4"	SC	.13
15		Hardware Cloth 16 mesh, 40" wide	SC	60	.28					Black Steel Pipe Std. 3/4"	SC	.13
16		Glass Substitute Latch Mesh	SC	80	.8					Friction Tape	FT	.10
		Hardware								Circuit Breaker, Multi-breaker	SC	.25
17		Joint Tape 5/8"	SC	10	.4					2-1 Pole-15 amp	SC	
18		T Hinge 6"	SC	16						Lamps		
19		Thumb Latch 2 1/2" 26	SC	2						Transistor 60watt, 120volt	SC	.5
20		Door Spring 16 1/2" 26	SC	24							SC	1

Figure 4-4. Finalized bill of materials.

SELF TEST

Note: The following exercises comprise a self test. The figures following each question refer to a paragraph containing information related to the question. Write your answer in the space provided below each question. When you have finished answering all the questions of this lesson, compare your answers with those given for this lesson in the back of this booklet. Review the lesson as necessary. Do not send in your solutions to these review exercises.

1. Estimating is one of the most important steps in planning a construction project. In what way does good estimating help insure successful completion of a project? (Para 4-1a)

2. What is the first step an estimator should take when assigned to a new project? (Para 4-1b(1))

3. Where does the estimator obtain the information he needs to prepare the bill of materials? (Para 4-1b(3))

4. Plans and specifications for bridges, buildings, and other vertical structures normally contain bills of materials. What is the function of the material estimator if alterations or modifications of the plans are necessary? (Para 4-3a)

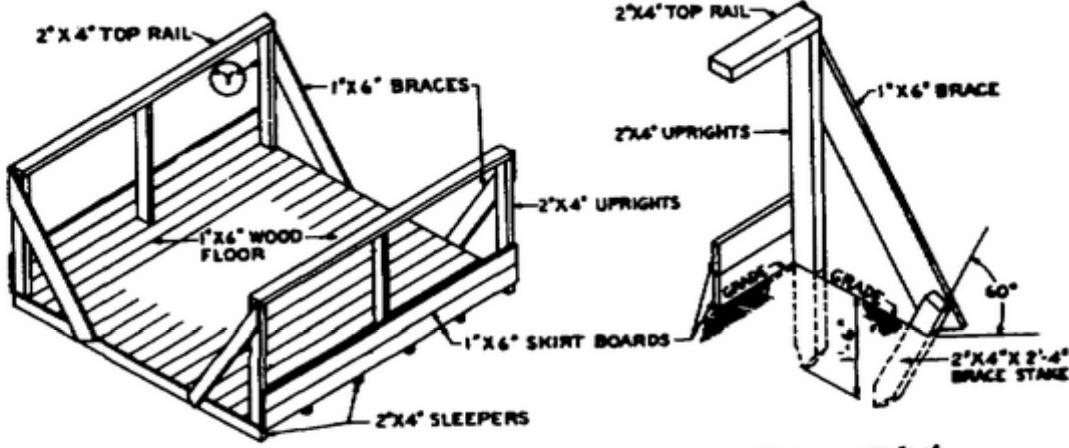
5. List the five essential elements of any bill of materials. (Para 4-4a)

6. In reference to the preparation of a takeoff list, what is the meaning of the rule "keep it separate?" (Para 4-5b(1))

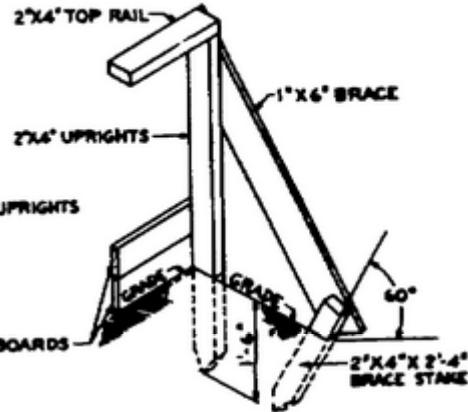
7. When the materials estimator converts the actual requirements for a certain size of lumber into the number of pieces of standard lengths to be procured, what is his primary consideration? (Para 4-5b(3))

Note: Review exercises 8 through 14 assume a knowledge of the takeoff form described in paragraph 4-5c and your ability to read details from figure 4-5.

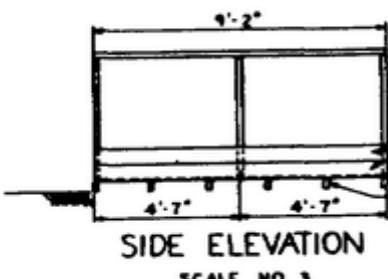
8. The wood floor of the tent frame shown in fig. 4-5 is nailed to 2" x 4" sleepers. What entry do you make in columns 3 and 5 on the takeoff form to cover sleepers? (Para 4-5c, 4-6, fig. 4-5)
9. Figure 4-5 shows skirtboards installed on each side of the tent frame. What is your entry in column 4 for skirt boards? (Para 4-5c, 4-6, fig. 4-5)
10. Bracing must be used to make the frame rigid. What are entries for columns 4 and 5 in regard to bracing? (Para 4-5c, 4-6, fig. 4-5)
11. Most of the common sized lumber is stocked in lengths ranging from 8 to 20 feet in 2-foot intervals. What is the general rule to observe in selection of standard lengths for column six of the takeoff list? (Para 4-6b(1))
12. What standard length 1 x 6 floor material would you enter in column 6 for the tent frame illustrated in figure 4-5? (Para 4-5c, 4-6, fig. 4-5)
13. When constructing an earth floor tent frame the sides are anchored to brace stakes. What standard length should you enter in column 6 for brace stakes? (Para 4-5c, 4-6, fig. 4-5)
14. Having determined in exercise 13 the standard length of 2 x 4 material required for brace stakes, what entry do you make in column 7 on the brace stake line? (Para 4-5c, 4-6, fig. 4-5)



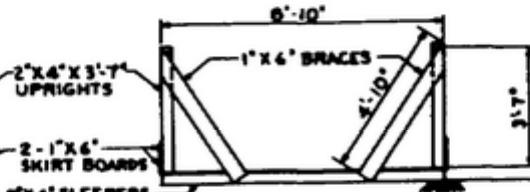
FRAME - OFFICERS TENT
NO SCALE



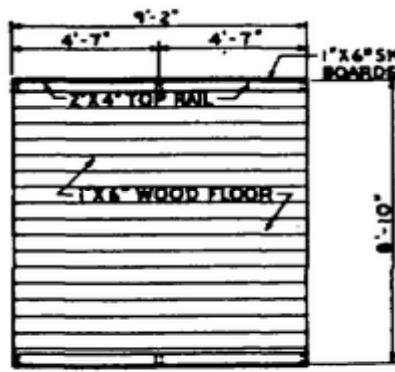
DETAIL AT "Y"
EARTH FLOOR
SCALE NO. 5



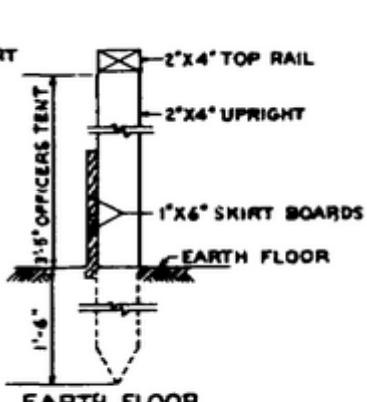
SIDE ELEVATION
SCALE NO. 3



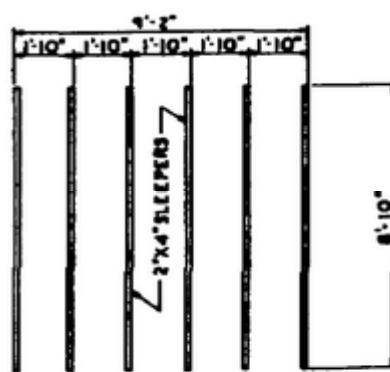
END ELEVATION
SCALE NO. 3



FLOORING PLAN
SCALE NO. 3



UPRIGHT DETAILS
SCALE NO. 7



FRAMING PLAN
SCALE NO. 3

Figure 4-5. For use with exercises 8 through 14.

15. Referring to figure 4-2, how do you arrive at the figure to enter in column 8? (Para 4-6b(2))
16. Consolidation on a bill of materials is the process of combining into one listing all identical items, regardless of nomenclature. Of the seven items listed in figure 4-2, which cannot be consolidated with any of the others? (Para 4-7b(3))
17. In figure 4-2, items 2, 4, 5, and 6 are identical. When they are consolidated, why does the entry in column 6 change? (Para 4-6c(2))
18. How much waste allowance is made for dimension lumber two or more inches thick? (Para 4-8, table 4-1)
19. Nail requirements are expressed in pounds of nails. Using the method outlined in paragraph 4-1, how many pounds of eight-penny nails will be required for 1500 square feet of sheathing? (Para 4-9f)
20. The last element in the preparation of a bill of materials is grouping and arranging. What benefit is to be realized from grouping and arranging? (Para 4-10)

LESSON 5

CONSTRUCTION METHODS AND STANDARDS PLANNING ESTIMATES

CREDIT HOURS.....	2
TEXT ASSIGNMENT.....	Attached memorandum.
MATERIALS REQUIRED.....	None.
SUGGESTIONS.....	Review pars 1-28 through 1-31, lesson 1.

LESSON OBJECTIVES

Upon completion of this lesson you should be able to accomplish the following in the indicated topic areas:

1. Reference texts and the Army Facilities Components System (AFCS). Be able to locate and use such construction information as needed from the library sets provided to engineer construction units, and the Army Technical Manuals which constitute the AFSC.

2. Labor estimates. Prepare labor estimates for a TO type construction based upon

criteria given in the technical manuals of AFCS.

3. Methods of erection. Evaluate the various methods of erection commonly used and determine which is the most suitable for the existing situation.

4. Nuclear warfare considerations. Make necessary changes in construction standards as governed by Department of the Army policy and outlines in appropriate directives, when the possibility of nuclear warfare must be considered.

ATTACHED MEMORANDUM

5-1. SUGGESTIONS

Building operations, like other engineering activities, provide a continuing challenge to the engineer's resourcefulness and construction know-how. Within the scope of this subcourse, it is possible only to introduce you to fundamentals, but mention should be made of reference works that will help you to solve other building problems that you may encounter in the field.

a. Library reference sets. Provision is made in tables of organization and equipment for library reference sets which contain standard civilian texts and handbooks on subjects pertinent to the

mission of the unit. Current authorizations for engineer construction units include the following works:

Handbook of Heavy Construction, Stubbs;
Data Book for Civil Engineers, Vol. II,
Specifications and Costs, Seelye;
Architectural Graphic Standards, Ramsey
and Sleeper;
Construction Estimates and Costs, Pulver;
Electrical Engineers Handbook, Electrical
Power, Pender and Delmar;

Surveying Theory and Practices, Davis and Foote.

Although these works are oriented to civilian needs, much of the material is applicable to military construction. The Handbook of Heavy Construction is a particularly useful reference for the study of the elements of structural theory, design principles, and strength of materials.

b. Army publications. In addition to the above, there are a number of Army publications which deal with various construction and related subjects. You will find these publications indexed in DA pamphlets 310-3 and 310-4. It is not the intent of this subcourse to cover those in detail; however, certain information will be given.

5-2. REQUISITIONS

After material requirements for a building-construction project have been determined, requisitions are prepared carefully, checked, and forwarded through properly designated supply channels. They should be submitted at the earliest possible date to insure delivery of materials in time to maintain progress schedules.

a. Quantities. When bills of material are prepared according to the methods outlined in lesson 4, quantities are taken directly from the bill. Appropriate waste allowances must be added to the quantities.

b. Nomenclature. All items should be requisitioned by the nomenclature, stock number, and unit of measure specified in Department of the Army supply catalogs. Items not listed are requisitioned by the most commonly used American nomenclature.

5-3. INNOVATIONS IN SUPPLY PROCEDURE

The Army Facilities Components System (AFCS), (formerly known as the Engineer Functional Components System (EFCS)), makes it possible to requisition all the materials for installations, facilities, or equipages (a 500-man troop camp, a 750-bed hospital, a 4000-man PW camp, etc.) as an end item. This eliminates the tremendous amount of paper work and requisitions which were formerly

involved when the component materials were ordered separately.

a. Need for AFCS. Because there was lack of design standardization, both in the types of buildings and in the facilities provided in the field, the Army designed the AFCS. The AFCS is explained in detail in TM 5-301, TM 5-302, and TM 5-303. These three manuals constitute a construction management tool in that they provide standards of construction, phases of construction, standard plans, bills of material, labor and cost estimates, logistic data, and equipages designed to provide or augment the equipment required for the execution of specific types of construction forces in various world areas. Construction units are thereby relieved of much of the task of designing, and preparing drawings, specifications, and bills of materials. In addition, the system is adaptable to automatic data processing (ADP) in determining the overall requirements for construction support of military operations in a TO. It is not the intent of this subcourse to provide a complete knowledge of the AFCS, but rather to provide a familiarization in its use.

b. Concept. In the three manuals mentioned above, the requirements for engineer effort and material are tabulated in terms of installations, facilities, and equipages; engineer effort is expressed in manhours; and material is expressed by cubage (measurement ton, MT, 40 cu ft/ton) and by weight (short ton, ST, 2,000 lb/ton).

(1) TM 5-301, Staff Tables of Army Facilities Components System. This manual contains tabulated logistical data in the form of staff tables for all installations, facilities, and equipages in the AFCS. It also contains basic definitions and descriptions of the system as well as its use and coding.

(2) TM 5-302, Construction in the Theater of Operations. This manual provides general construction drawings based upon accepted design standards, and special construction details, with simplified bills of materials for various installations and facilities. It does NOT present logistical data as to engineer effort, weight and cubage requirements.

(3) TM 5-303, Bills of Materials and Equipment of the Army Facilities Components System. This manual contains complete bills of materials for each facility covered by staff tables in TM 5-301 and by the drawings in TM 5-302, as well as equipages for various construction tasks in specific climates. It also provides material costs and the logistical data concerning engineer effort, weight, and cubage requirements as in TM 5-301.

c. Organization. In the application of the AFCS, it is important to remember that it is based on an orderly grouping of successively larger increments so that planning can be done by functional groupings rather than by individual items. In this respect AFCS uses a system of coding to permit exploitation of ADP equipment. The system establishes three groups: installations, facilities, and equipages.

(1) Installations. The largest groupings in AFCS are installations - a balanced grouping of facilities in support of a particular major function. The breakdown of installations into facilities permits the tailoring of installations to meet particular situations. Each installation is identified by a code consisting of one to three capital letters and four numbers made up of one whole number and three decimals.

(2) Facilities. The basic elements of the AFCS are facilities - a grouping of items consisting primarily of construction material in the quantities required to provide a specific service. Each facility is coded with a six-digit number. The first four digits of the facility code number group similar functional facilities together, and also constitute the drawing number of the facility as presented in TM 5-302. The last two numbers of the six-digit code identify the bill of materials table for the facility.

(3) Equipages. Equipage lists consist primarily of nonexpendable construction equipment. They are designed to assist planners in developing equipment augmentation to TOE equipment to provide engineer units and civilian labor units with the capabilities of efficiently performing specific construction tasks in specific climates. Equipage lists are based on sustained operations on a given task for periods of two to three months. They specify

additional quantities of mission-type items already contained in TOE's as well as special equipment required for specific tasks. Each equipage is coded with the letter E and a five-digit number.

(4) Indexing. Each of the three AFCS manuals mentioned above is indexed in such a manner as to enable the user to readily locate the installations and/or facilities required to support most military operations, independent of each other. However, in the use of TM 5-302 and TM 5-303, it is more expedient to:

(a) First, refer to the index of TM 5-301.

(b) Second, locate the staff table pertinent to the required installation, facility or equipage.

(c) Third, identify by coding and then refer to TM 5-302 for drawings and TM 5-303 for bills of materials as appropriate.

d. Key to coding.

(1) Installations. Installations are identified by a code consisting of one, two, or three letters of the alphabet followed by a four-digit number consisting of one whole number and three decimals.

Example - NT-1.131 would be a Troop Camp, 250 Man, Temperate Climate Standard 3, New Construction, Steel Frame Buildings.

(a) Letter codes. The first letter of an installation classifies it according to its functional grouping as follows:

- A - Administration
- D - General Supply
- F - Transportation
- G - Medical
- H - Aviation
- J - Shops
- N - Camps
- P - Utility Plants
- Q - Bulk POL
- S - Special

Additional letters identifying subgroupings are used to simplify use of the system. These

letters, normally alphabetical abbreviations of subgroups, are added as needed.

Example -

A - Administration
AP - Post Office
AR - Recreation

(b) First digit codes. The first digit of the code of an installation indicates its size relationship to other installations provided for the same function.

Example:

1st digit	Installation
1 -----	250 Man Troop Camp
2 -----	500 Man Troop Camp
3 -----	1,000 Man Troop Camp
4 -----	1,500 Man Troop Camp

(c) Second digit codes. The second digit of the code indicates the climatic or terrain condition in the area for which the installation is planned. Installations are not developed at this time for all climatic and terrain conditions. Code assignments for this digit are as follows:

2d digit	Climate or terrain
0.0 -----	All Climates
0.1 -----	Temperate Climate
0.2 -----	Tropical Climate
0.3 -----	Frigid Climate
0.4 -----	Arctic Climate
0.5 -----	Temperate and Tropical
0.6 -----	All Terrain
0.7 -----	Generally Rolling or Average Terrain
0.8 -----	Mountainous Terrain
0.9 -----	Desert

(d) Third digit codes. The third digit of the code indicates the theater of operations standard of construction. Increasing numbers indicate greater degrees of permanency of accommodations. The degree of permanency will depend upon command policies, operational necessity and availability of construction materials and effort. Standards of construction vary with each functional grouping. For example, in storage installations the degree of permanency is based on the proportion of covered storage in buildings instead of tents.

(e) Fourth digit codes. The fourth digit of the code indicates the nature of the task involved in providing the installation. Code numbers are assigned as follows:

4th digit code	Nature of task
0.000 -----	An Engineer service; no construction involved
0.001 -----	New construction, steel frame
0.002 -----	New construction, wood frame
0.003 -----	Increase in degree of permanency — steel frame construction
0.004 -----	Increase in degree of permanency — wood frame construction
0.005 -----	New construction combination, steel and wood frame
0.006 -----	POL construction
0.007 -----	Other construction
0.008 -----	Rehabilitation
0.009 -----	Maintenance

(f) Example. An example of the coding system for installations is as follows:

Code NT-1.131

NT Functional group	1 Size	.1 Climate or terrain	3 Standard of construction	1 Nature of task
Troop camp	250 Man	Temperate	Standard 3	New construction steel frame buildings

(g) Installation staff tables arranged in orders of functional groupings.

A - Administration
AP - Post Offices

AR - Recreation Installation
BB - Barrier Systems
BC - Field Fortifications
BD - Obstacle Reduction

C	- Communications	ND	- Military Prisoner Stockades
D	- General Supply	NP	- POW amps
DA	- Ammo Storage	NT	- Troop Camp
DS	- Cargo Storage	P	- Utility Plants
F	- Transportation	PE	- Power Generation
FB	- Bridging	PS	- Sewage Treatment
FP	- Ports	PW	- Water Supply
FR	- Regulating Station	Q	- Bulk POL
FT	- Terminal	QA	- Marine Terminals
G	- Medical	QB and QBT	- Tank Farms
H	- Aviation	QC	- Tank Farm Complexes
HA	- Army Airfield	QD	- Pipe Lines
J	- Shops.	QE	- Drum and Can Loading Plants
N	- Camps		

(h) Standards of construction for Troop Camps. Standards of construction for troop camp and other types of installations are designated by the second digit following the decimal point. This digit ranges from 1 through 6 with corresponding theater of operations standards of construction for troop camp installations as indicated below -

Code digit	Standard of construction	Description
1	1	TOE tents; no engineer materials or effort involved.
2	2	Class IV tents pitched by using troops; engineer effort for roads and site preparation.
3	3	Buildings with floors for administration, bathhouses, infirmaries, storehouses, and kitchens. Class VI tents with floors for housing and with earth floors for all other purposes. Roads within the installations are stabilized with local materials. Water piped from central storage tank to infirmaries, bathhouses, and kitchens. Electric distribution to buildings. Pit type latrines.
4	4	Buildings with floors for all purposes except housing; Class IV tents with floors and wood frames for housing; roads within the installations are stabilized with local materials; water piped from central storage tank to infirmaries, bathhouses, kitchens, and camp exchange; electric distribution to buildings and tent housing. Pit type latrines.
5	5	Buildings with floors for all purposes. Roads, water supply, and latrines are the same as type 4 above; electric distribution to all buildings.
6	6	Buildings with floors for all purposes; latrines with pipe to carry untreated sewage 1,000 feet beyond the confines of the camp; bituminous surfacing of roads within the installations; water piped from central storage tank to infirmary, bathhouses, latrines, kitchens, and camp exchange; electric distribution to all buildings.

(2) Facilities. Facilities normally are identified by a code consisting of a six-digit number.

In certain facilities, the code consists of a five-digit number and one letter.

Example: 441101 would be a storehouse 20 feet x 50 feet, interior only.

(a) **Six digit codes.** The first three numbers of the six-digit number catalog facilities in groupings similar to the method in which they are cataloged in the current Department of Defense coding system for real property inventories. This coding gives planners the capability of directly comparing existing oversea US facilities with those planned for in any particular oversea theater. The breakdown of this coding is as follows -

1. The first digit identifies the facility groupings indicated below:

1st digit	Group
0	Combat Support
1	Airfields
2	Maintenance and Production
3	Building Details
4	Storage
5	Hospital and Medical
6	Administration
7	Housing
8	Utilities and Ground Improvements
9	Site Preparation

2. Addition of the second digit identifies the facility in further detail. **Example:**

1st two digits	Group
41	POL Storage
42	Ammunition Storage

43	Refrigerated Storage
44	Warehouses and Sheds
45	Open Storage

3. Addition of the third digit specifically identifies the basic facility category. **Example:**

1st three digits	Basic facility category
421	Ammunition Storage Depot and Arsenal
422	Ammunition Storage Installation and Ready Issue
423	Ammunition Storage, Liquid Propellant

4. The first four digits of the facility code number constitute the identifying code number for drawings pertaining to the facility. **Example:**

1st four digits	Facility drawing
4221	Storage, Ammo, Steel, 20 feet x 60 feet

5. The last two numbers of the six digit numbers are added as needed to identify the bill of material of the facility.

6. The first three numbers of this coding system are based on the Department of Defense coding system for facility classes and construction categories.

(b) **Example.** An example of the coding system of facilities is given below-

Code 441101

1st Digit	1st Two Digits	1st Three Digits	1st Four Digits	Last Two Digits
Facility Group	Facility Group	Basic Facility	Facility	Facility
Storage	Details, Warehouses and Sheds	Category, Depot and Arsenal Covered Storage	Drawing Number, Interior Layout	Bill of Material, Interior Only

(3) **Equipage.** Equipages are identified by one letter and five digit numbers as follows:

Example: E-02109 would be an Armored Engineer Battalion Western Europe, Road.

(a) Letter and Five Digit Codes:

1. The letter E is used to differentiate the coding system from those used for installations and facilitates.

2. The first two digits identify the equipages according to type of engineer unit for which the augmentation is planned as indicated below:

1st two digits	Type unit
01 -----	Airborne Engineer Battalion
02 -----	Armored Engineer Battalion
03 -----	Engineer Camouflage Company
04 -----	Civilian Labor, Local Contractor
05 -----	Civilian Labor, Military Supervised
06 -----	Engineer Combat Battalion, Army
07 -----	Engineer Combat Battalion, Divisional
08 -----	Engineer Construction Battalion
09 -----	Engineer Port Construction Company

3. Addition of the third digit identifies equipages as to geographical area as indicated-

3d digit	Geographical area
1 -----	Western Europe
2 -----	Eastern Europe
3 -----	Middle East
4 -----	Southeast Asia
5 -----	China
6 -----	Alaska

4. The 4th and 5th digits of the code indicate the task for which the unit is being augmented:

4th and 5th digits	Task
01 -----	Bridging, Highway
02 -----	Bridging, Railroad
03 -----	Building
04 -----	Deception
05 -----	Petroleum Storage
06 -----	Port
07 -----	Protective
08 -----	Railroad
09 -----	Road
10 -----	Runway, Light Aircraft
11 -----	Tunnel

(b) **Example.** An example of the coding system is given below -

Code E-08109

(c) **Details.** Equipage lists were compiled under the following assumptions:

1. All units will be at full strength.
2. Sufficient personnel will be available within units to operate augmented items and to perform equipment maintenance.
3. Tactical missions not considered.
4. Units will be equipped on a self-sustaining basis (exception: civilian labor units).
5. Rehabilitation and new construction will be on an austere basis.
6. Equipment will be operated in one or more localities and will be used simultaneously or successively on various aspects of the work.
7. Military units will operate on a two-shift basis.
8. Civilian units will operate on a two-shift basis where feasible.

5-4. LABOR ESTIMATES

For the engineer officer assigned to construction duty a sound working knowledge of materials estimating procedure is one essential of effective planning. In addition to materials estimating, he will also be expected, on most projects, to estimate labor requirements in order to establish a construction-operations plan or schedule for the purpose of coordinating activities on the job and for securing the most efficient use of men, materials, and equipment.

a. The total manhours required for the construction of prefabricated standard-frame TO structures and related facilities are published in TM 5-301. These data are

largely derived from experiences with civilian contracts. In a theater of operations, these rates must be modified according to climate, terrain, extent of enemy interference and other conditions. Consequently they are primarily intended to be used as planning guides rather than as production standards.

b. Detailed labor production estimate.

Company and battalion progress schedules and output records of comparable work performed under similar conditions are the most reliable bases for estimating labor capabilities. This is one of the major reasons why it is so important that engineer units keep detailed, accurate records of all work accomplished. If such data are not available, the construction handbook and manuals to which you were referred previously contain information on average labor production for various building operations. The engineer officer must use good judgment and sound knowledge of construction principles in applying these standard estimates to his particular building operations. He should take into account such factors as: experience and training of personnel, availability of special tools and equipment and materials, method of cutting and assembling components, erection procedures, and weather and climate conditions.

5-5. INFLUENCE OF CLIMATE ON DESIGN

a. Temperate climate. Unless otherwise indicated, standard plans provide minimum requirements for a temperate climate. No special factors influence this design. Floors are earth, wood, or concrete, as necessary. Heating is by individual stoves and ventilation by adequate doors and windows. Roof framing shown on standard plans is designed for a snow load of 15 pounds per square foot. If heavier loads of snow can be partially removed, stronger original framing is unnecessary. Wet snow approximately 6 inches deep or dry snow approximately 18 inches deep weighs about 15 pounds per square foot. Standard buildings are designed to resist normal wind forces of 10 pounds per square foot. In areas where high wind velocities occur, all buildings should be anchored by guys instead of redesigned as to framing.

b. Frigid climate. The extremes of frigid weather require modification of temperate-climate plans. Floors are laid double thick and walls and roof are insulated. Woodfloor buildings have skirting to the ground. Heating is by individual stoves. Door and window openings are small, sufficient only to provide adequate ventilation. Since standard roof framing is designed for snow loads of only 15 pounds per square foot, roof construction must be strengthened if partial clearing of heavier snow from roofs is impractical. Resistance to high wind velocities should be provided by guy wires, when necessary.

c. Tropical climate. Floor plans for temperate climates are also used in tropical climates, but are modified to provide as much circulation of air as possible. Most buildings have wood floors, raised above ground to insure dryness and to prevent mildew and the entrance of insects. Use of continuous screened openings, ridge vents, and floorlevel vents provides the maximum ventilation possible, consistent with the shelter required. Overhanging eaves exclude the direct rays of the sun and protect openings during rainstorms. To protect the building against termites, all wood members touching the ground should be treated and have metal shields installed to prevent insect infestation. Resistance to high wind velocities should be provided by guy wires, when necessary.

5-6. CONCRETE FLOORS

Concrete floors are often used in TO construction, especially for latrines, bathhouses, repair and assembly shops, and certain types of warehouses where earthen or wooden floors are not suitable. These floors are made by placing the concrete on the ground after the earth has been graded and tamped. This type of floor is likely to be damp unless protected. Drainage is provided, both for the floor area and for the area near the floor, to prevent flooding after heavy rains. The floor should be reinforced with steel or wire mesh. Where concrete floors are to be placed, a foundation wall may be placed first and the

floor placed after the superstructure is completed. This provides protection to the concrete floor while it sets and eliminates the waiting period that must otherwise follow before construction of the building can begin.

5-7. METHODS OF ERECTION

a. **General.** The method of erecting buildings directly affects the time, labor, and material needed. The methods may be divided into two types.

(1) **Built in place.** In this method each piece is separately erected in its proper place.

(2) **Panel method.** In this method a complete section is built up as a unit and then set in the building in the proper place. It is used extensively because it makes for greater speed, better control over working parties and better use of manpower. It also allows the use of a standard list of sizes for each similar section; standard plans shown in TM 5-302 further simplify construction.

b. **Factors considered in selection of method to be used.** Construction planning permits an orderly series of operations and prevents duplication of effort and waste of material. Factors considered in planning are construction plant layout, distribution of material, number of skilled and semiskilled men available, and number and type of units to be constructed. From a list of the various separate operations required, an estimate of the total number of man-hours needed is made. This estimate forms the basis for determining the number and type of men needed and for organizing the erection crew or crews. Arrangements for assembling the necessary materials at the job site and for doing the preliminary cutting and assembly are made in advance.

c. **Procedures, built-in-place method.** When using the built-in-place method, the officer in charge of construction divides the men into working parties, whose duties may be as follows:

- (1) Laying out the foundation.
- (2) Grading and excavating.
- (3) Laying out and cutting various sizes of material.
- (4) Carrying material to the cutting and erecting parties.

If a party completes its task before the building is completed, it is assigned a new task. For example, if the party laying out the foundation completes its work before erection of the building is begun, it is assigned a new duty such as cutting rafters. Parts are built in the following order: footings, piers, sills, joists, floor, sole, studs, plates, girts, rafters, bracing, siding, sheathing, roofing, doors, windows, steps, and inside finish (if used).

d. **Procedures, panel method.** The panel method (presassembly method) requires careful planning before the actual construction. Most Army buildings are now built by this method, as follows:

(1) Before measuring and cutting lumber, the number and size of sections that are alike should be determined from the blueprint. This insures the correct numbers of each piece. The carpenter assigns a crew to cut and assemble one section. In most cases, a template is built as a guide for assembling the section. It should be built square, correct in size, and level. Most TO construction now built by the panel method uses the basic 8 foot by 10 foot panel (fig. 51) with special door panels, window panels, and modified panels. Modified panels are smaller by the actual width of a 2 x 4 and are used as end panels. Detailed drawings of this type panel construction including roof and gable panel are included in TM 5-302.

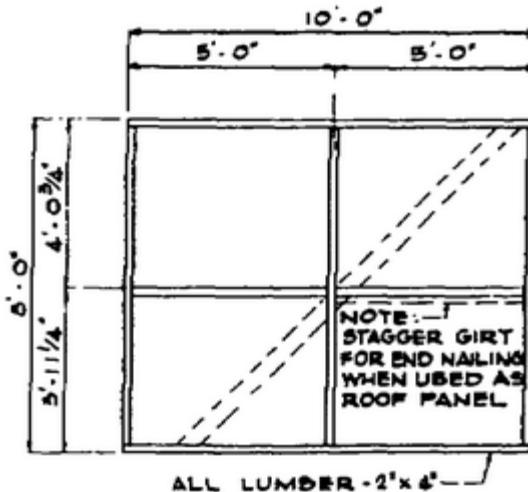


Figure 5-1. Basic wall panel.

(2) The number and size of each piece in a section is given to the man in charge of the cutting party. The cutting party cuts the timber to the correct length with a handsaw or power saw. The length is measured by the use of square and tape. After one piece has been cut, it may be used as a pattern for marking the remaining pieces. The pattern is set up by nailing two blocks to the piece of correct size, one near each end, as shown in figure 5-2. These blocks act as stops to hold the pattern in place on the timber to be marked. Several cutting and assembling parties may be used at one time on different types of sections.

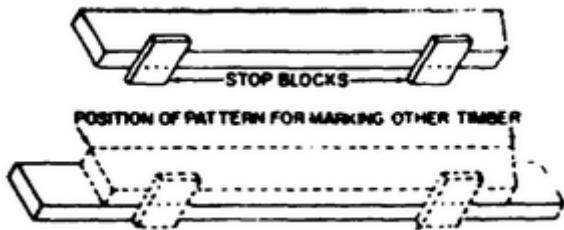


Figure 5-2. Marking a pattern

(3) The plate and sole are placed in the template with the studs and girts between; then the door and window posts, if any, are placed (fig. 5-3). The girts, sole, and plate are nailed to the studs with 16- or 20-penny nails. If insulation board is used, it and the wall sheathing are put on the section before it is taken out of the template. By applying the wall finish before raising the section, no scaffold or ladders need be used.

(4) The erecting party sets the sections into place, braces them temporarily, and nails them together. The end section should be first, and it may be erected on graded earth. The sidewall sections are next and should be erected so as to keep the two walls even. The rafter party can then place the rafters on the walls. Parties should be set up as follows: layout party, cutting party, assembling party, carrying party, erecting party for rafters, sheathing party, roofing party, and door-and-window party.

(5) The preassembly method of erection may be used for all types of small buildings and large warehouses. When this method is used for large buildings, cranes are

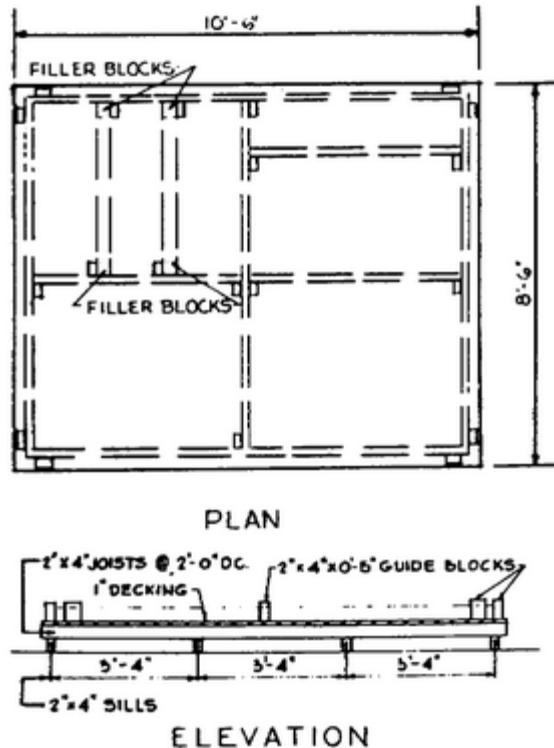


Figure 5-3. Template for wall panels.

used to place sections too heavy to be handled by hand. Where machinery is used, caution in fastening the cable or rope avoids damaging the section.

5-8. NUCLEAR WEAPONS FACTORS IN THEATER-OF-OPERATIONS CONSTRUCTION

Changes in construction standards resulting from possible increased use of nuclear weapons are governed by Department of the Army policy and will normally be outlined by TO or other appropriate directives. General considerations, as they pertain to this subcourse, involve probable effects on structures and possible precautionary measures to minimize damage.

a. Damage to structures and material in a nuclear explosion is due to blast and shock, and fire. Fires may be started by thermal radiation, but most will be extinguished by the blast. The majority of fires will be from secondary causes as indirect blast effects. Wooden, brick, and light steel frame buildings are highly vulnerable to blast. In open

terrain, high air bursts can be expected to produce severe structural damage at distances ranging from 1300 meters for a 2 kt bomb to 8000 meters for a bomb yielding 500 kt. Underground shock will cause water, sewer, and gas mains to suffer severely, but electric mains will not be greatly affected.

b. Although nuclear weapons possess unprecedented destructive capabilities, it is not to be assumed that defensive measures cannot lessen their effectiveness. Some general precautions are listed below:

(1) Take advantage of natural terrain. A hill mask can reduce structural damage considerably at distances comparatively close to ground zero.

(2) Use glass-substitute material.

(3) Observe minimum-spacing requirements.

(4) In some instances it may be advisable to dig in or to partially bury certain structures.

(5) Provide for an adequate water supply.

(6) If materials are available, use non-inflammable exterior finish, and additional bracing at structural joints.

5-9. NONSTANDARD CONSTRUCTION

a. Although standard plans are normally used in meeting requirement for new construction in a TO, climate conditions lack of standard materials, transportation shortages, availability of local materials and labor, or other considerations may make it necessary or advisable to modify these

typical designs. Nonstandard construction may be classified generally as follows:

(1) Substitute construction which involves the modification of standard plans or use of substitute materials.

(2) Expedient construction which uses materials of any type. It may not be economical of labor or materials, but its employment is warranted to get the job done.

(3) Improvised construction which is the simplest type suitable for immediate needs.

b. In addition to new construction involving standard or nonstandard structures, a good portion of the engineer effort in some theaters is directed to repairing and adapting existing structures for military usage.

5-10. REFERENCES AND TABLES

Although this subcourse aims primarily at covering the fundamentals of standard-type TO construction, you were given in paragraph 5-1 for this lesson a list of reference works which provide information on nonstandard construction and related subjects. It is not possible here to cover in detail the use of these manuals, but it is believed that some of the exercises for this lesson will illustrate how reference materials can be used in solving typical problems which may arise in modifying standard structures, in designing nonstandard buildings, or in repairing existing structures. Tables 5-1, 5-2, 5-3, 5-4, and 5-5, and examples of their use (in the self-test) are extracted from FM 5-35, Engineers' Reference and Logistical Data.

TABLE 5-1. *Working stresses.*

Species and grade description (1)	Stress grade: (2)	Average unit weight ¹ (lb per cu ft) (3)	Allowable working stresses for military use ¹ (lb per sq in)				Modulus of elasticity (8)
			Extreme fiber stress in bending ¹ (4)	Horizontal shear (5)	Compression perpendicular to grain ¹ (6)	Compression parallel to grain ¹ (7)	
UNITED STATES SPECIES							
Douglas fir		35	2,700 2,400 2,100	180 150 180	500 450 500	1,950 1,800 1,650	1,600,000
Dense, select structural	1,800f						
Select structural	1,600f						
Yellow pine (longleaf, or dense shortleaf)	1,400f						
Select structural	2,000f		40	3,000 2,700	150 150	500 500	2,200 1,950
Prime structural	1,800f						
Merchantable structural; and structural square edge and sound	1,600f			2,400 2,100	150 150	500 500	1,800 1,500
No. 1 structural	1,400f						
Larch		36					
Select structural	1,800f			2,700	200	500	1,950
Structural	1,600f			2,400	150	470	1,800
Common structural	1,200f			1,800	135	430	1,650
Redwood (structural)		30					
Dense, select, all heart	1,400f			2,100	135	350	1,800
Select, all heart	1,200f			1,800	120	350	1,650
Bulkhead and heart	1,000f			1,650	120	350	1,500
Southern cypress		32					
Select structural	1,400f			2,100	180	400	1,800
Structural	1,100f			1,650	150	400	1,500
Eastern hemlock		30					
Select structural	1,100f			1,650	105	400	1,050

¹ Reduce all stresses to 70 percent of tabular values for green wood and for design of parts of bridge structure continuously wet. Reduce all stress values to 75 percent of tabular values for design of structures carrying long-continued live load.

² Grade designations of structural timber adopted by United States lumber industry for long-time use.

³ At about 15 percent moisture content.

⁴ Working stresses for compression parallel to grain apply to posts, columns, and struts the unsupported length of which does not exceed 11 times least dimension of cross section.

Allowable working stresses in pounds per square inch for various domestic species of wood, including the unit weight and modulus of elasticity, are as follows:

TABLE 5-2. Beam Stresses.

Timber beams are designed using the standard beam formulas and the unit stresses in table I. For beams in which flexure controls, the following table is used:

Span (ft)	Safe loads in pounds uniformly distributed for rectangular beams per inch of actual width (For allowable fiber stress of 1,000 psi)										Nominal depth of beam (inches)
	4	6	8	10	12	14	16	18	20	22	
4	370	880	1,560	2,510	3,670	5,060					
6	240	590	1,040	1,670	2,450	3,380					
8	180	440	780	1,260	1,840	2,530					
10	150	350	630	1,000	1,470	2,020	2,670	3,400	4,220	5,140	6,140
12	120	290	520	840	1,220	1,690	2,220	2,840	3,520	4,280	5,110
14	100	250	450	720	1,050	1,450	1,900	2,430	3,020	3,660	4,380
16	90	220	390	630	920	1,260	1,670	2,120	2,640	3,220	3,840
18	80	200	350	560	820	1,120	1,480	1,890	2,340	2,860	3,400
20	70	180	310	500	730	1,010	1,330	1,700	2,110	2,570	3,060
22	60	280	460	670	920	1,210	1,540	1,920	2,340	2,790	
24	50	260	420	610	840	1,110	1,420	1,760	2,140	2,560	
26	44	240	390	560	780	1,030	1,310	1,620	1,980	2,380	
28	38	220	360	530	720	950	1,210	1,510	1,830	2,190	
30	32	210	330	490	670	890	1,130	1,410	1,710	2,040	
32	28	200	310	460	630	830	1,060	1,320	1,610	1,920	
34	24	180	290	430	590	780	1,000	1,240	1,510	1,810	

Note 1. For fiber stresses other than 1,000 psi, change safe loads proportionately.

Note 2. Example. What is the safe uniformly distributed load on a beam 8" x 14" of select structural Douglas fir on a 16-foot span? Assume warehouse door service in which live loads can be applied over long periods.

Solution. From table I, the fiber stress is 2400 x .75, or 1800 psi. (see note 1 below table I) for select structural fir subjected to long continued loads. From the table above, the safe load at 1,000 psi is 1,260 lb per inch of width. The actual width of an 8-inch surfaced timber is 7½ inches. The safe load is then

$$\frac{7\frac{1}{2}}{1,260} \times \frac{1,800}{1,000} = 17,010 \text{ pounds}$$

At 35 pounds per cubic foot the beam weighs about 435 pounds. This is about 2½ percent of the total safe load and normally can be neglected.

TABLE 5-3. *Beam Design, Horizontal Shear*

Safe loads in pounds uniformly distributed for rectangular beams, per inch of actual width (For allowable horizontal shear of 100 psi)					
Nominal depth, inches	Safe load, pounds	Depth, inches	Safe load, pounds	Depth, inches	Safe load, pounds
4 -----	480	12	1,530	20	2,600
6 -----	750	14	1,800	22	2,870
8 -----	1,000	16	2,060	24	3,130
10 -----	1,260	18	2,330	-----	-----

Note 1. For allowable stresses other than 100 psi, change safe loads proportionately.

Note 2. Example. Assume the 8" x 14" beam in the example in note 2, table II, is used on a 10-foot span. The allowable load due to flexure is:

$$7\frac{1}{2} \times 2,060 \times \frac{1,000}{1,000} = 27,270 \text{ pounds}$$

Allowable load due to horizontal shear: Stress is given as 150 psi in table I

$$7\frac{1}{2} \times 1,800 \times \frac{150}{100} = 20,250 \text{ pounds}$$

In this case the shear controls the allowable load.

(When using table III to calculate horizontal shear use the full tabular value in column 5, table I; make no allowance for long-continued stress.)

TABLE 5-4. *Column Design*

Square Columns. Safe axial load in kips for square timber columns: (For allowable compression parallel to grain of 1,100 psi)				
Nominal size (inches)	Actual size (inches)	Area (square inches)	Length (feet)	Safe load (kips)
6 x 6 -----	5½ x 5½	30.3	8	26.0
			10	24.2
			12	22.4
8 x 8 -----	7½ x 7½	56.3	8	52.0
			10	49.5
			12	47.0
			14	44.5
			16	42.0
			18	39.6
10 x 10 -----	9½ x 9½	90.2	8	86.8
			10	83.6
			12	80.1
			14	77.2
			16	74.3
			18	71.0
			20	67.8
12 x 12 -----	11½ x 11½	132.2	8	130.5
			10	127.0
			12	123.0
			14	119.0
			16	115.2
			18	111.3
			20	109.5

Note 1. Safe load on a round column is 0.785 times the safe load on a square column of side equal to diameter.

1 kip = 1000 lb.

Note 2. For loads on columns of various grades and species, proportion from the loads tabulated above, using allowable compression stresses parallel to grain from column 7 of table I. For example, a select structural Douglas-fir column in warehouse service has an allowable stress of 75 percent of 1,800 or 1,350 psi.

Such a column 10" x 10" x 12' carries $80.1 \times \frac{1,350}{1,100} = 98.3$ kips.

TABLE 5-5. *Average Construction Rates for Building Parts Installed by Carpenters*

Parts	Dimensions (in)	Amount installed per man per 10-hr day
Girders	2 x 6	350 BF
Plates, studs, and girts	2 x 4	300 BF
Floor joists	2 x 6	480 BF
Rafters	2 x 4	240 BF
Flooring	1 x 6 S4S	600 BF
Sheathing (wall)	1 vertical	480 BF
Sheathing (roof)	1 horizontal	600 BF
Rolled roofing	—	800 sq ft

SELF TEST

Note: The following exercises comprise a self test. The figures following each question refer to a paragraph containing information related to the question. Write your answer in the space provided below each question. When you have finished answering all the questions for this lesson, compare your answers with those given for this lesson in the back of this booklet. Review the lesson as necessary. Do not send in your solutions to these review exercises.

1. In the preparation of requisitions for materials for a construction project, how are the quantity requirements of each item determined? (Para 5-2a)
2. What advantage does the Army Facilities Components System (AFCS) provide in the requisitioning of materials for a construction project? (Para 5-3)
3. TM's 5-301, 5-302, and 5-303 explain the AFCS in detail. In general terms, in what way are they helpful to the construction unit, other than in requisitioning of construction materials? (Para 5-3a)
4. One of the TM's in support of the AFCS provides construction drawings and standards and special construction details. Which of the TM's contains that information? (Para 5-3b(2))
5. The AFCS is based upon an orderly grouping of successively larger increments so that planning can be done by functional groupings rather than by individual items. Name the three major groupings of the AFCS. (Para 5-3c)
6. Codes are used for convenience and to save time in identifying groupings and subgroupings within the AFCS. How could you immediately determine that a certain code referred to an installation? (Para 5-3d(1))
7. Briefly state the details of an installation identified by code N-3.212. (Para 5-3s(1))

8. Installation staff tables are arranged alphabetically in order of functional groupings. What is the code for military prisoner stockades? (Para 5-3d(1)(g))
9. The second major grouping of the AFCS is facilities. What characteristics identify a facilities code? (Para 5-3d(2))
10. The third major grouping of the AFCS is equipages. What is the format of an equipage code? (Para 5-3d(3))
11. Total manhour requirements for the construction of prefabricated standard-frame TO structures and related facilities are published in TM 5-301. What is the primary use for this information? (Para 5-4a)
12. Standard plans provide minimum requirements for construction in temperate climates. If wind velocity is anticipated above 10 pounds per square foot, what building modifications are made? (Para 5-5a)
13. A shop building is to be constructed with a concrete floor. At what stage of the building construction is it best to pour the concrete to avoid construction delays? (Para 5-6)
14. Joists, piers, sills, floor, and footings are five parts of a TO building. Arrange them in the sequence in which they should be constructed. (Para 5-7c)
15. When erecting a building using the panel method, an end section is set up first, followed by the two sides. Why should the sides be brought out at an even rate? (Para 5-7d(4))

16. Damage to structures and material in a nuclear explosion is due to blast, shock, and fire. Explain order of nuclear explosion effects that cause most fire damage. (Para 5-8a)

17. Of the three classes of nonstandard construction outlined in this lesson, which is probably the least economical of labor and materials? (Para 5-9a(2))

18. A truck on a construction job can have a maximum of 5000 pounds of 10-foot lumber. If the lumber is long leaf yellow pine with a moisture content of 15 percent, how many board feet can this truck haul? (Table 5-1)

19. For supporting piers in a warehouse, structural larch timbers 10 x 10 are available for use. When used in 8-foot lengths what safe axial load will these timbers support? (Tables 5-1, 5-4)

20. Materials for the roof of a building will consist of: 660 BF 2 x 4 (rafters), 1500 BF 1 x 6 (sheathing), 1100 sq ft (roll roofing). Cold weather will lower production to 70 percent. How many days will the roof construction require if four qualified carpenters work at 10-hour days? (Table 5-5)

LESSON 1

ANSWERS TO SELF TEST

1. Permanent buildings, 25 years or more; semipermanent buildings, less than 25 years and more than 5 years; temporary buildings, 5 years or less (para 1-1).
2. Drawings or sketches are needed to convey necessary information to the individual who will fabricate the building (para 1-2b).
3. A thin (light) line composed of alternate long and short dashes is called a center line and is used to divide objects into equal or symmetrical parts (para 1-3c).
4. Architects scales are generally used in scaling drawings for machine and structural work (para 1-4a(1)).
5. The plan view shows the type, size, and location of mechanical equipment such as heating plant, radiators, plumbing, and electrical wiring (para 1-5b(8)).
6. The miter butt joint is used in framing for rafter junctions at roof peaks (para 1-8c).
7. Joints are connections between two pieces of lumber or timber that come together at an angle (para 1-8). Splices are connections between two pieces that extend in the same line (para 1-9).
8. The Army uses mainly softwoods in TO construction (para 1-10a).
9. Dry rot is the most common and the most dangerous type of wood decay (para 1-13a).
10. Number 4 common lumber is mostly used for construction of boxes and crates (para 1-16b(4)).
11. The term **board foot** means the volume of a board 1 inch thick, 1 foot wide, and 1 foot long (para 1-18a).
12. Nails are generally considered to be the cheapest, and bolts provide the greatest amount of holding power (para 1-20a).
13. Split ring timber connectors are used between two timber faces in heavy construction to increase the joint strength (para 1-25b(1)).
14. Column (pier) foundations save time, labor, and material and are used whenever possible in TO construction (para 1-27).
15. The sill is the foundation on which all framing structure rests, and it is the basic point of departure for actual carpentry and joinery activities (para 1-29a).
16. Girders are needed to support floor joists wherever the width or length of the structure makes it impossible to use joists over the full span (para 1-30a).

17. The bottom ends of the cross bridging are not nailed until the subfloor or finish floor is laid and nailed to the joists so the joists will adjust themselves to their final position (para 1-33).
18. After having established the baseline, it is usually advisable with an irregularly shaped building, to lay out first a large rectangle which will comprise the entire building or the greater part of it (para 1-39).
19. If the height of batter boards is more than three feet above the ground, they should be braced (para 1-40c).
20. Lines between batter boards can be made approximately level by attaching a line level at the midpoint of the line and making necessary adjustments (para 1-41e).

LESSON 2

ANSWERS TO SELF TEST

1. The bearing strength of stud walls is determined by the strength of the studs (para 2-1).
2. A stud called a "T-post" is used wherever a partition meets an outside wall. This member provides a solid nailing base for the inside wall finish (para 2-1b).
3. Studs may be placed 4 feet apart if girts are used (para 2-1d(1)).
4. The walls must be plumbed and straightened after the corner posts, T-posts and intermediate studs have been nailed to the plates and the girts but before the permanent braces and rafters have been installed (para 2-2).
5. Internal diagonal bracing is used when no interior finish is planned (para 2-3d).
6. Gable roofs are most commonly used by the Army because they are simple to design, economical to construct, and may be used on any type of structure (para 2-4a).
7. $3/9 = x/12; 9x = 36; x = 4$. Therefore, you would have 4 inches of rise per foot of run (para 2-4e).
8. Total run is one-half the span distance, which was given as 20 ft 6 in. Therefore, total run in this case is 10 ft 3 in (para 2-4f(1)(3)).
9. Rafters, ridge boards, and plates are the three principal members of a roof frame (para 2-5b).
10. Bowed rafters should always be installed with the bow up (para 2-6b(2)).
11. $24 / 2 = 12$ feet total run. On figure 2-17 find the run-rise line for 12 run - 6 rise. Move to right to 12 on main scale and read 13 ft 5 inches for rafter length (para 2-6d(3)).
12. Collar beams are horizontal ties between two rafters placed somewhere between the roof ridge and the top plate. The nearer they are to the top plate the better they perform their main function, which is to prevent the building walls from spreading. This type of bracing is used in the roofs of small buildings where no ceiling joists are used (para 2-7).
13. The primary function of the rafters is to carry the roof loads to the studs (para 2-8b(1)).
14. The trussed rafter system permits use of smaller size lumber and more economical use of manpower (para 2-8e)
15. When trussed rafters are used, the ridge board is eliminated (para 2-8d).
16. Knee braces may be installed on each rafter truss if severe winds are anticipated, and may be spaced as widely as 16 feet on centers where wind is not a serious problem (para 2-8e).
17. A compression member requires a greater sectional area for a given stress than does a tension member (para 2-9b)

18. Before holes are bored the timbers are selected, measured, and cut. They are then laid in position, nailed temporarily and the bore holes located. Bore hole locations are rechecked, then bored (para 2-9e)
19. Purlins for large roofs are continuous members which rest on the trusses. In small roof construction short purlins are inserted between the rafters and toe nailed to them (para 2-10).
20. For residential construction in the U.S. studs are normally installed on 16-inch centers. In TO type construction, studs are frequently spaced as much as 8 feet on center, in which case girts must be used to provide stiffness to the wall and nailing bases for the siding (para 2-11b).

LESSON 3

ANSWERS TO SELF TEST

1. Plywood has approximately equal strength in both length and width, has greater resistance to checking and splitting, is less affected by changes in moisture content, provides more bracing effect, and requires less labor in installation (para 3-**b**).
2. "One-in-three" spacing means that the space left between sheathing boards is twice the width of the boards. It is used when corrugated sheet metal or other strong, large-panel material is used for roof covering (para 3-**c**).
3. Corrugated sheet metal and prepared (roll) roofing (para 3-4).
4. When using corrugated sheet metal roofing, the roof slope must not be less than four inches per foot of run. Therefore: $10 \times 4 = 40$ inches, or 3' - 4" total rise (para 3-5**a**)
5. Rafter line length = 11'- 4"
Overhang = $\frac{2'}{13' - 4''} = 13\frac{1}{3}$ feet
 $60 \times 13\frac{1}{3} \times 2$ (no. of slopes) = 1600 sq ft
 $1600 \div 80 = 20$ rolls required.
6. Roof slopes of less than 1 inch per foot require multilayer built-up roofing (para 3-5**b**).
7. A flashing is installed, made up of either two layers of roll roofing, or a strip of sheet metal (para 3-6).
8. Where rafters have no overhang, the first piece of sheathing is placed on the rafters so that it hangs over the rafters 3 to 4 inches (para 3-8**b**)
9. When corrugated sheet metal is used, it should overhang the sheathing from 1 to 2 inches on the gable ends as well as on the eaves, to provide added protection to the walls (para 3-8**c**).
10. Vertical sheathing helps to support the roof load on the top plate, while horizontal sheathing does not (para 3-9**b**).
11. Drop and shiplap siding have a rabbeted edge to give the proper lap. The lap must be measured each time in applying bevel siding, which requires much time (para 3-9**c**).
12. Asphaltic felt or tar paper used behind sheet iron will cause the metal to rust (para 3-9**d**).
13. The interior door frame is constructed like the exterior door frame except that no casing is used on inside door frames (para 3-10**c**).
14. The hinges are fastened to the battens of the door and to the hinge blocks on the door casing or post (para 3-10**d**).

15. Wainscoting is installed to protect finish walls which are subject to damage. It is made of wood, plywood, or other strong building material and covers the bottom 3 or 4 feet of an interior finish wall (para 3-10h).
16. Finish flooring is laid perpendicular to the floor joists (para 3-10i).
17. Assume 6 1/2 inch rise,
 $38 / 6.5 = 5.85$, use 6 risers
Then, $38 / 6 = 6.33$ or 6 1/3 inches actual rise
From first rule of thumb:
 $18 - 6 \frac{1}{3} = 11 \frac{2}{3}$ inches = tread
From second rule of thumb:
 $6.33 \times 11.67 = 73.8$ inches (is between 70 and 75 inches, therefore within limits)
18. The bottom riser is always less than the other risers by the thickness of the tread. Thickness of 2 x 12 lumber is actually 1 1/2 inches. Therefore $7 - 1 \frac{1}{2} = 5 \frac{1}{2}$ inches, height cut for bottom riser (para 3-12c, c(4)).
19. When a roof jack is not available, the sheathing and other wood should be at least 6 inches from the stovepipe (para 3-14a).
20. When the stovepipe goes out through the wall, no flashing is required. A piece of sheet metal slightly larger than the wall opening, with a hole the size of the pipe, is necessary. This is nailed over the opening in the wall (para 3-14b(1)).

LESSON 4

ANSWERS TO SELF TEST

1. Good estimating helps to insure completion of projects on time and the economical use of men, materials, and equipment (para 4-1a).
2. The first thing an estimator should do is to become thoroughly familiar with the project by studying the plans and specifications and the work site itself (para 4-1b(1)).
3. Information for preparing the bill of materials is obtained from drawings and specifications (para 4-1b(3)).
4. If plans are altered or modified, the materials estimator will have to make the required additions and deletions to the accompanying bills (para 4-3a).
5. No matter what system is used in the preparation of a bill of materials, the following five elements are essential (para 4-4a).
 - a. Take-off list
 - b. Consolidation
 - c. Waste allowance
 - d. Nail requirements
 - e. Grouping and arranging
6. Parts are always listed separately unless size and nomenclature are identical (para 4-5b(1)).
7. When determining the number of pieces of standard length lumber required, the materials estimator must determine the standard length that will produce the most parts with the least waste (para 4-5b(3)).
8. In column 3 enter 6 (number of pieces) and in column 5 enter 8'10" (length in place) (para 4-5c, 4-6, fig. 4-5).
9. Nominal size of skirtboards is 1" x 6" which is entered in column 4 (para 4-5c, 4-6, fig. 4-5).
10. In column 4 enter 1" x 6" (nominal size) and in column 5 enter 4'10" (length in place) (para 4-5c, 4-6, fig. 4-5).
11. The shortest standard length which supplies the most pieces with the least waste is normally chosen (para 4-6b(1)).
12. From the floor plan in figure 4-5 it is determined that the length in place of the 1 x 6's is 9'2". A standard 10-footer would have 10" of waste. Any other standard length would have more waste except a 20-footer which would provide 2 pieces and have 20" waste. Therefore, by the rule cited in exercise 11, a standard 10-footer would be chosen (para 4-5c, 4-6, fig. 4-5).

13. To develop column 6, try a 10-foot length.

$2'-4"$ = length of brace stake (fig. 4-5) converting to inches:

$$10'-0" = 10 \times 12 = 120 \text{ inches}$$

$$2'-4" = (2 \times 12) + 4 = 28 \text{ inches}$$

$$120 / 28 = 4 \text{ pieces, with } 8" \text{ waste}$$

Continued calculations will show that a 12-footer will supply 5 pieces with only 4 inches waste, but since only 4 pieces are required the waste would be $2'-8"$. Therefore, the 10-foot standard length is selected (para 4-5c, 4-6, fig. 4-5).

14. Four pieces can be cut from a ten foot standard length, so 4 is the correct entry for column 7 of the take-off-list (para 4-5c, 4-6, fig. 4-5).

15. The number of standard lengths required, the entry for column 8, is developed by dividing the figure in column 3 (number of pieces) by the figure in column 7 (number of pieces per standard length) (para 4-6b(2)).

16. Note that item 7 (nominal size 2 x 6) is not identical with any other item, therefore cannot be consolidated with any other (para 4-7b(3)).

17. When items 2, 4, 5, and 6 are consolidated, the total number of 3-foot pieces becomes nine. Calculations shown in paragraph 4-6c(2)) indicate that there is less waste in obtaining nine 3-foot pieces from 10-foot lengths than from 8-foot lengths (para 4-6c(2)).

18. From table 4-1, a 10% waste allowance is included for dimension lumber two or more inches thick (para 4-8, table 4-1).

19. Since 20 pounds of 8-penny nails are required for 1000 square feet of sheathing, then:
 $1500 = 1.5 \text{ MBF}$
 $1.5 \times 20 = 30 \text{ lbs required (para 4-9f).}$

20. Grouping and arranging results in a completed bill of materials which facilitates requisitioning (para 4-10).

LESSON 5

ANSWERS TO SELF TEST

1. Quantities of each item required are taken directly from the bills of materials (para 5-2a).
2. The AFCS makes it possible to requisition all the materials for installations, facilities, or equipages as an end item (para 5-3).
3. The three manuals constitute a construction management tool in that they provide standards of construction, phases of construction, standard plans, bills of materials, labor and cost estimates, logistic data, and equipages designed to provide or augment the equipment required for the execution of specific types of construction forces in various world areas (para 5-3a).
4. TM 5-302 provides general construction drawings based upon accepted design standards, and special construction details with simplified bills of materials (para 5-3b(2)).
5. The three major groupings within the AFCS are: Installations, Facilities, and Equipages (para 5-3c).
6. Installations are identified by a code consisting of one, two, or three letters of the alphabet followed by a four-digit number consisting of one whole number and three decimals (para 5-3d(1)).
7. Code N-3.212 specifies the following: N = camps; 3 = 1,000 man troop camp; .2 = tropical climate; .01 = lowest standard of construction per theater of command policy; .002 = new construction, wood frame (para 5-3d(1))
8. The code for military prisoner stockades is ND (para 5-3d(1)(g)).
9. Facilities normally are identified by a code consisting of a six-digit number. For certain facilities, the code consists of a five-digit number and one letter (para 5-3d(2)).
10. Equipages are identified by codes made up of the letter E and five digits (para 5-3d(3)).
11. Manhour requirements published in TM 5-301 are primarily intended to be used as planning guides rather than as production standards (para 5-4a).
12. In areas where high wind velocities occur, all buildings should be anchored by guys instead of redesigning the framing (para 5-5a).
13. The concrete floor should be placed after the superstructure is completed to eliminate the waiting period while the concrete hardens (para 5-6).
14. The five items listed would be constructed in the following sequence: footings, piers, sills, joists, and floor (para 5-7c).
15. After one end is set up, the two sidewalls are erected at an even rate so that the rafter party can commence the installation of trusses or rafters sooner (para 5-7d(4)).

16. Fires may be started by thermal radiation, but most of these will be extinguished by the blast. The majority of fires will be from secondary causes as indirect blast effects (para 5-8a).
17. Expedient construction uses materials of any type. It may not be economical of labor or materials, but its employment is warranted to get the job done (para 5-9a(2)).
18. From table 5-1 find that longleaf yellow pine weighs 40 pounds per cubic foot at 15% moisture content. Then, $5000 / 40 = 125$ cu ft allowable load. Since 1 cu ft = 12 board feet, $125 \times 12 = 1500$ board feet truck can haul (table 5-1).
19. From table 5-4, a 10 x 10 post 8 feet in length can support 86.8 kips. Since table 5-4 is based upon an allowable compression parallel to the grain of 1100 psi, the actual value for structural larch must be used. From table 5-1, column 7, read 1800 psi. Per note 1, take 75% of 1800 = 1350 psi.

$$\text{Then } 86.8 \times \frac{1350}{1100} = 106.3 \text{ kips (tables 5-1, 5-4).}$$

20. One man working under normal conditions will require the following times:

$$\text{rafters } \frac{660}{240} = 2.75 \text{ days}$$

$$\text{sheathing } \frac{1500}{600} = 2.50 \text{ days}$$

$$\text{roofing } \frac{1100}{800} = \frac{1.375}{6.625} \text{ days}$$

Four men would require:

$$\frac{6.625}{4} = 1.656 \text{ days}$$

Cold weather reduces efficiency to 70%:

$$\frac{1.656}{.70} = 2.36, \text{ say } 2.4 \text{ days (table 5-5).}$$